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Gato-Class Submarines

Warships Number 28

in action

Squadron Signal Publications

Gato-Class Submarines
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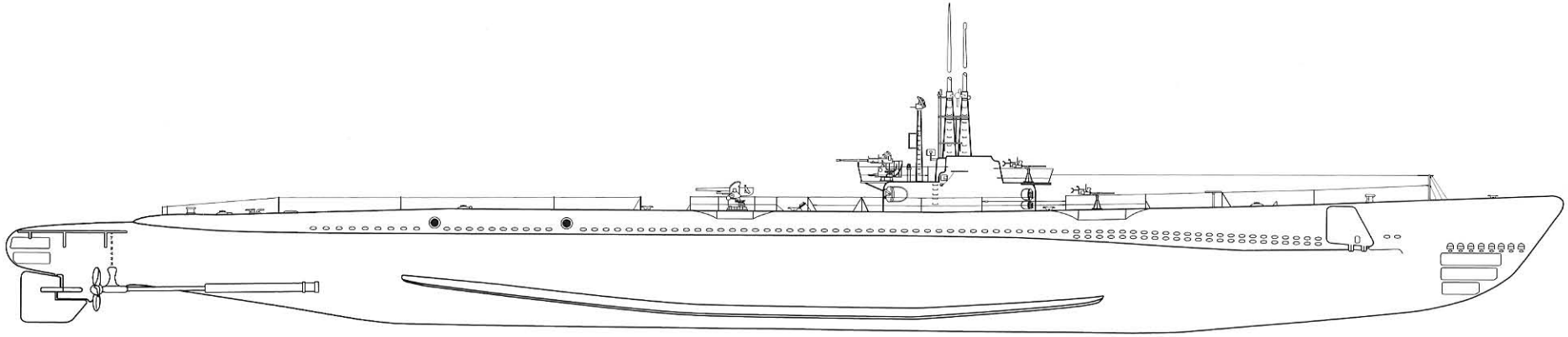
By Robert C. Stern

Color by Don Greer



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Cover: *Batfish* (SS 310) sinks the Japanese submarine *RO-112* late in the evening of 11 February 1945 north of Aparri, off the north coast of Luzon. *RO-112* was there to rescue pilots and aircrew stranded after U.S. air attacks destroyed their planes on the ground. *Batfish* was directed to the area by MAGIC intercepts and over the course of three nights in February 1945 sank two — possibly three — Japanese submarines, all assigned the same rescue mission. (Painting by Don Greer)

Acknowledgements

Many people have helped me gather this material and the information presented here. I list below the sources of photographs used in this work. In a few cases, I have failed to record the person who sent me a photograph; in those cases I credit the original source. All of these photographs had their origin with the U.S. Navy, but now reside in one of several archives and museums, and the credit given with each photograph is the person or organization that supplied the photograph or allowed me to copy it. I thank them all.

U.S. Navy, particularly the Defense Visual Information Center (USN)
National Archives and Records Administration, Suitland, Maryland (NARA)
Submarine Force Library & Museum, Groton, Connecticut (SFL)
Naval Historical Center, Washington, D.C. (NHC)
Navsource.com
Bob Cressman
Bill Crouch

I am, of course, supremely grateful to the men who fought in these boats and to the men and women who built them. I would be remiss if I didn't specifically acknowledge the efforts of the crews at Mare Island Naval Shipyard, who documented the many boats which passed through the main refit yard for *Gatos* during the war, leaving the photographic record on which this book depends.

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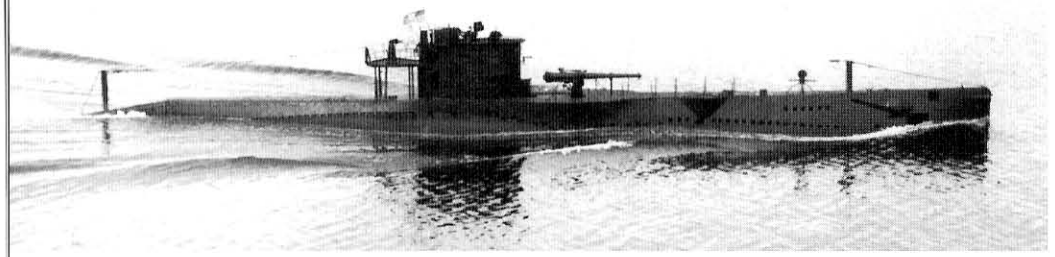
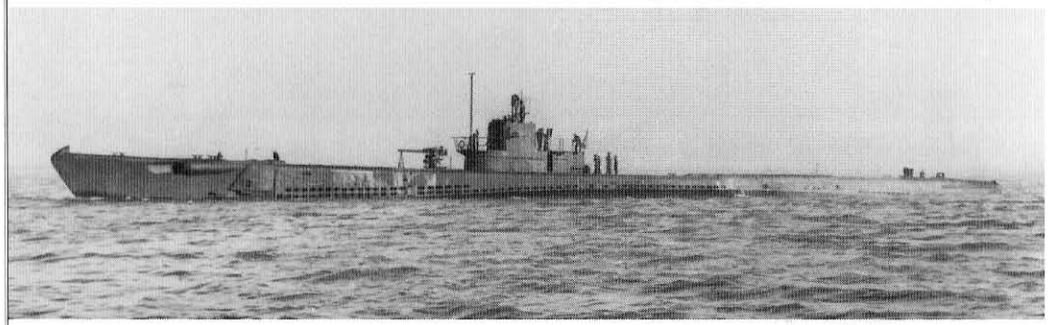
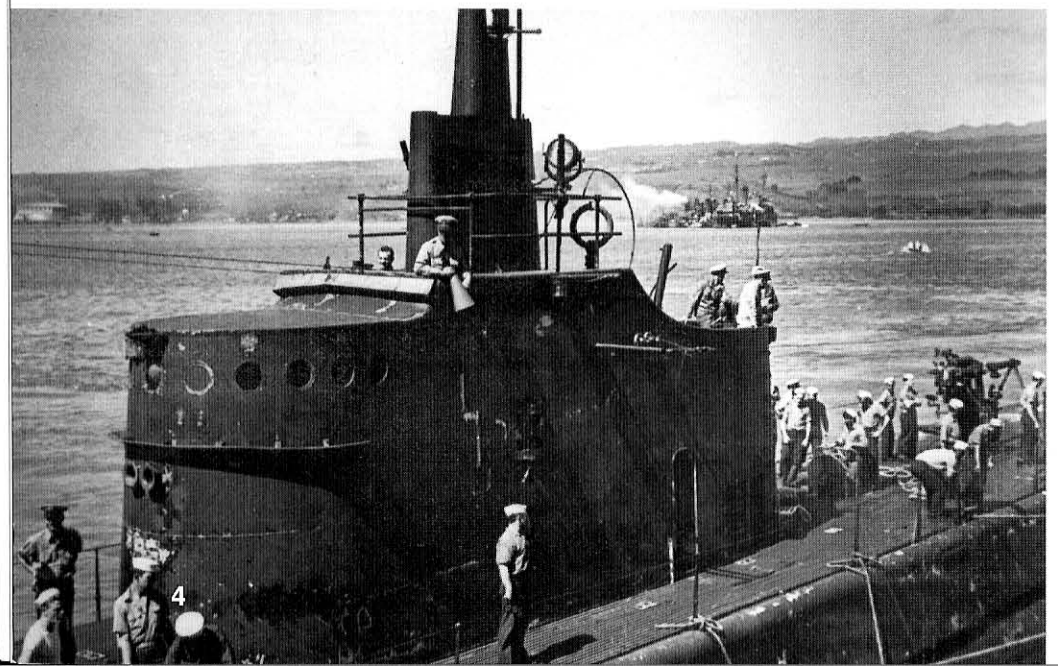
▸ ***Angler* (SS 240) backs away from the pier at the Submarine Base, Pearl Harbor, on 12 June 1945. She is on her way back to the war, having just completed a major overhaul at the Bethlehem Steel Company yard in San Francisco. She is in typical late-war configuration for a *Gato*, with cut-down tower plating, SJ and SD radars, a 40 mm gun on the forward cigarette deck, and a 5-inch gun aft of the tower. In the background are (left) a *Baltimore*-class heavy cruiser and (right), behind the long shed under the large crane, the battleship *North Carolina*. (NARA)**



▲ **Typical of the S-class boats built at the end of the First World War, *S-28* (SS 133), seen here off Seattle on 18 June 1943, survived into the 1940s and was used for training. Concessions to modernity include a 20 mm Oerlikon mount (minus the actual gun) in the makeshift cigarette deck aft of the tower and the sonar 'head' of the JK/QB combination forward of the 4-inch, 50-caliber deck gun. (NARA)**

▼ ***Permit* (SS 178) was a member of the P-class, one of the immediate design antecedents of the *Gatos*. She is seen here as she appeared on 13 January 1943 at Pearl Harbor between patrols. The obvious features that distinguished *Permit* from a *Gato* were the external torpedo tube visible at her bow and the placement of the SD mast forward of the conning tower. Other than that, it would be difficult to distinguish *Permit* from a mid-war *Gato*. (NHC)**





Fleet Submarines

The United States Navy was early to adopt submarine technology. The several experimental boats built for the Navy by John Holland in the last years of the nineteenth century are considered by many to have been the first practical submersibles. But whatever lead the U.S. Navy enjoyed over the rest of the world in those early days had long since slipped away by the end of World War I. By 1919, the United States was building submarines that were smaller, slower, less well armed, and shorter-ranged than the submarines that other combatants had deployed during the war.

As embarrassing as that situation was, it was even more of a concern given the changed strategic situation that emerged after the Great War. The United States was no longer a marginal player on the world stage, and, as a 'great power,' had to be prepared for the possibility that the peace brokered at Versailles would not last very long. There were really only two or, at the most, three nations the U.S. might conceivably face in any future war, and one of those, Great Britain, was a firm ally. Bolshevik Russia was scary, but not a military threat. That left Japan.

The Japanese Empire was young and growing rapidly at the expense of her neighbors. Japan was intent on making up for lost time in the race for imperial power and prestige. This was a policy that would inevitably lead to conflict with the older, more established imperial powers in Asia: France, Holland, Great Britain, and the United States. The Americans in particular were concerned because, alone on that list of nations, much of their empire was in the Pacific, directly in the path of Japanese expansion. The Philippines, Guam, Wake, and Hawaii were all major obstacles to Japanese dominance in the region. The United States concluded that it needed a navy capable of defending those island possessions and defeating the growing Japanese fleet.

It was obvious that the submarines the United States was building at the end of World War I would not meet the needs of a war in the Pacific. The S-class boats under construction at the end of the war compared poorly with late-war boats being built by Germany. The following table compares the characteristics of *S-10*, a mid-series S-class boat started in 1919, *U 135*, a large Mittel-U (mainstream submarine) built in 1917 and extensively tested by the Royal Navy after the war, and *U 140*, an even larger U-Kreuzer (submarine cruiser) intended for long-range missions, finished in 1918. *U 140* was turned over to the U.S. Navy at war's end and also extensively tested.

	S-10	***U 135***	***U 140***
Displacement (surface, tons)	930	1,175	1,930
Length	231 ft (70.4 m)	274 ft (83.5 m)	302 ft (92 m)
Speed (surface/submerged, knots)	14/11	17.6/8.1	15.8/7.6
Torpedo tubes/torpedoes carried	4/14	6/14	6/19
Gun(s)	1 x 4-inch	2 x 4.1-inch	2 x 5.9-inch 2 x 3.4-inch
Range, economical (nautical miles/knots)	7,121/9.6	10,000/8	12,630/8

For approximately a 25 percent increase in overall size, *U 135* outperformed the American design by significantly more than that margin in virtually every category of fighting characteristics.

◀ ***Trout* (SS 202), a *Tambor*-class boat, ties up at Pearl Harbor on 4 February 1942, carrying gold from the Philippine treasury as ballast. Only minor differences in the plated-in periscope shears distinguish this boat from an early *Gato*. At this date, she is without radar and has a water-cooled .50-caliber machine gun on her cigarette deck and a 3-inch, 50-caliber deck gun aft of her tower. The *Tambors* carried the brunt of the fighting in the first year of the war, before *Gatos* began to arrive in appreciable numbers. *Trout* was lost in early 1944 on her eleventh war patrol. (NARA)**

U 140 was even larger and carried even more weapons over a greater range. The message was clear: The U.S. Navy needed bigger, more capable boats to fight in the Pacific.

Money for shipbuilding was tight after the war, and the Navy had many needs, so submarine construction proceeded slowly. Nevertheless, funds were found to build nine largely experimental V-class boats during the 1920s and early 1930s. This was not a uniform class by any means; the nine V-boats were built to five different designs, as befits a navy experimenting with different solutions to a difficult strategic problem. They ranged from the huge *Argonaut*, a 2,700-ton minelayer, to the final two in the series, the much more reasonably sized *Cachalot* and *Cuttlefish* (*V-8* and *V-9*, respectively; later *C-1* and *C-2*) of 1,100 tons, modeled closely on *U 135*. These last two boats were by far the most successful, combining good speed and range with a size more amenable to series production. Additionally, the C-class introduced two important innovations: extensive use of welding, particularly in the hull, which saved weight, added strength, and eliminated the oil leakage which had plagued all previous American boats; and the installation of the first Torpedo Data Computer (TDC), an analog electromechanical calculator intended to help solve increasingly complex targeting equations.

Having found a basically satisfactory design with the *Cachalot*-class, the Navy now had the opportunity to build up a fleet of long-ranging and powerful boats. Under the leadership of a new president who believed that the way out of the Depression was to put people to work, the Navy found itself with enough money to build a significant number of submarines. Starting in 1933 with the P-class boats, a steady progression of submarine development began that would eventually result in the *Gato*-class of 1940.

P Class. Enlarged repeats of the *Cachalot* design, P-class boats were longer, faster, and had increased range, characteristics which made them popular. They introduced two valuable innovations to the design lineage: air conditioning and diesel-electric drive. The former was seen by many navies as an unwarranted luxury, but it improved the habitability of American boats on long patrols in tropical zones, and, more importantly, dramatically reduced the instance of electrical short circuits caused by condensation. *Perch*, which had the following characteristics, was the fifth of ten P-class boats. The first four had varying characteristics; the final six were similar.

	Perch
Displacement (surface, tons)	1,350
Length	300.5 ft (91.6 m)
Speed (surface/submerged, knots)	19.25/8.75
Torpedo tubes/torpedoes carried	6/16
Gun(s)	1 x 3"
Range, economical (nautical miles/knots)	11,000/10

The only complaint leveled against the P-class boats was the six torpedo tubes, a number which critics said was too few for a boat of that size. Five of the boats had a pair of external tubes added after war broke out in 1941. All served in the war, four being lost to enemy action.

Salmon/Sargo Class. Six *Salmon*-class and ten nearly identical *Sargo*-class boats followed directly after the P class. Besides being a few feet longer and approximately 100 tons heavier, they differed little from the preceding boats. The most significant difference was the addition of a pair of internal torpedo tubes aft, addressing the primary complaint against the P class. The last of these boats was laid down in 1938, just before the outbreak of war in Europe added even more urgency to America's rearmament. These boats in fact had a serious design flaw — the main induction valve was poorly designed and sometimes failed to close properly when the boat submerged. The fix for the problem was cheap and simple, but despite several close calls, nothing was done until *Squalus* sank during a test dive, killing twenty-three of her crew. All served with distinction in the Second World War (even *Squalus*, which was raised and renamed *Sailfish*). Four were lost. *Stingray* went on sixteen war patrols, the most of any U.S. submarine in the war.

Tambor Class. This class addressed the only real complaint against the *Salmon/Sargo*-class, namely, that eight torpedo tubes were still considered too few. Therefore, *Tambor* and her sisters added two more tubes forward for a total of ten. The specifications of the twelve boats of this class were as follows:

	Tambor
Displacement (surface, tons)	1,475
Length	307.2 ft (93.6 m)
Speed (surface/submerged, knots)	20.4/8.75
Torpedo tubes/torpedoes carried	10/24
Gun(s)	1 x 3"
Range, economical (nautical miles/knots)	11,000/10

The *Tambors* were the last boats to be completed before Pearl Harbor and, as such, they bore the brunt of fighting in the first year of the war. Seven were lost in the war. One of the survivors, *Tautog*, had the distinction of sinking more enemy ships than any other American boat.

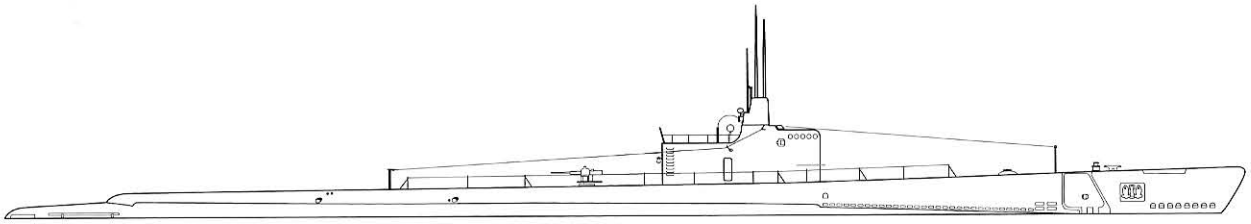
A small, but vocal, faction in the Navy thought American boats had gotten too big and fancy with their air conditioning and TDCs and pressured the General Board into ordering two submarines barely half the size of *Tambor*. *Mackerel* and *Marlin* were fine boats, bigger than the German Type VII, smaller than the Type IX, but extremely unpopular with the Submarine Force, because they had less of everything they liked in the big 'fleet' boats. The main argument for the smaller boats was that fleet submarines were too big to mass-produce should American find itself in the European war. Fleet boat proponents acknowledged this but countered simply that U.S. submarines would have no role to play in the Battle of the Atlantic. (This was a half-dozen years before the idea would emerge that submarines made the best anti-submarine platform. Several generations of sensor technologies — particularly sonar technologies — would have to be developed and proven in combat before that idea would become self-evident.)

The Navy's submarines would be deployed almost exclusively in the Pacific, and in that theater, *Mackerel* and *Marlin* were inadequate in virtually every respect. Navy submariners successfully argued that the next boats should be very nearly identical repeats of the *Tambor* class. The original Fiscal Year (FY) 1941 budget included funds for six of these slightly improved *Tambors* — the *Gato* class. With minor variations that led to two identifiable sub-classes — the *Balao* and *Tench* classes — this was the boat with which American would prosecute and win the war with Japan.

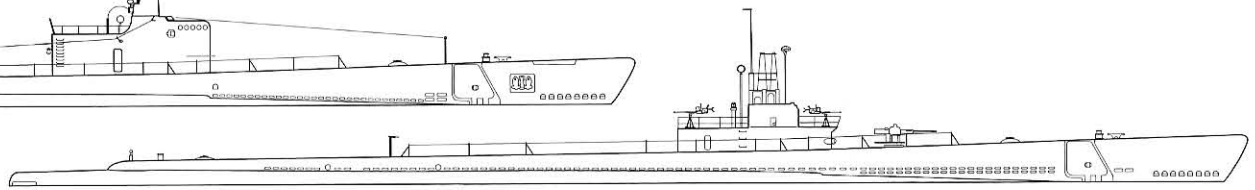
Note: The term 'fleet submarine' is used to describe all the full-sized boats in this line of development, starting with *Barracuda* (*V-1*) all the way through the last *Tench*-class boat delivered in 1951. Only the relatively diminutive *Mackerel* and *Marlin* were not part of this group. The concept of a fleet submarine emerged at the end of World War I, the idea being that a large and fast submarine could keep up with a navy's main battle fleet and perform scouting and interdiction functions in support of the fleet. This idea might have worked had battleships remained the large, slow behemoths they were before that war, but after the war, capital ship speeds soon increased to the point that even the largest submarine couldn't keep up. However, the Navy retained the term despite the fact that its tactical doctrine moved away from using submarines to support battle groups and towards employing submarines as independent raiders preying on enemy shipping in places the fleet's surface ships could never go. That these submarines were sometimes used in direct support of fleet operations, such as in lifeguard missions rescuing downed pilots during carrier raids, simply reflects their unique ability to approach enemy shores that no other type of boat in the fleet possessed.

(▸▸ 7)

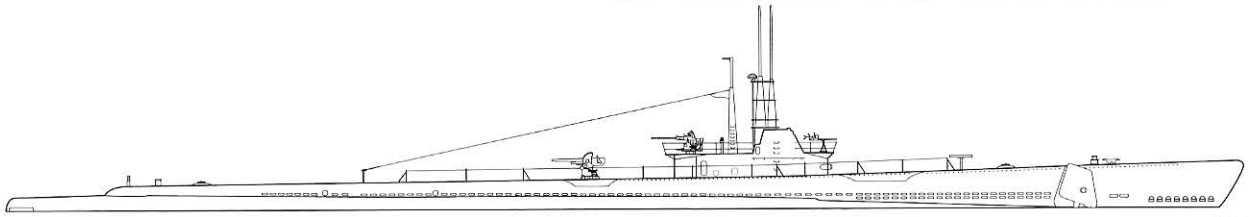
Development



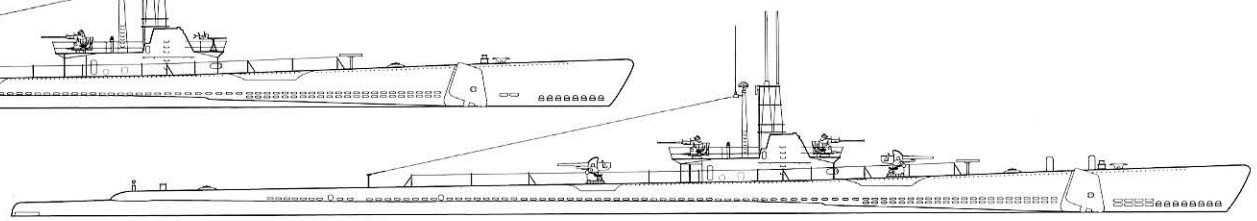
▲ *Greenling* (SS 213), January 1942



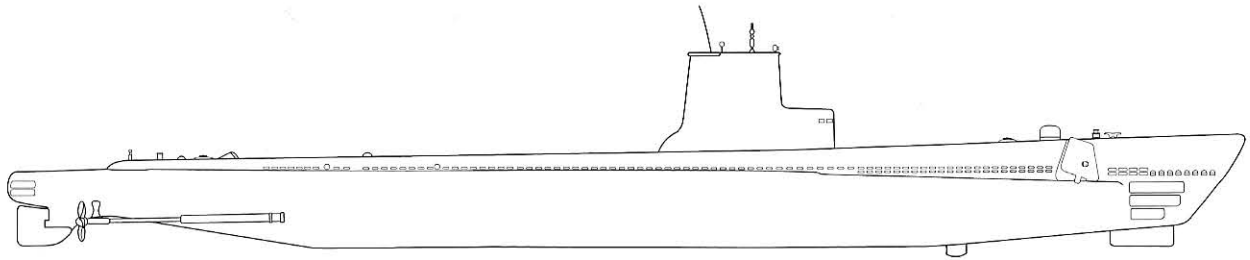
▲ *Wahoo* (SS 238), July 1943



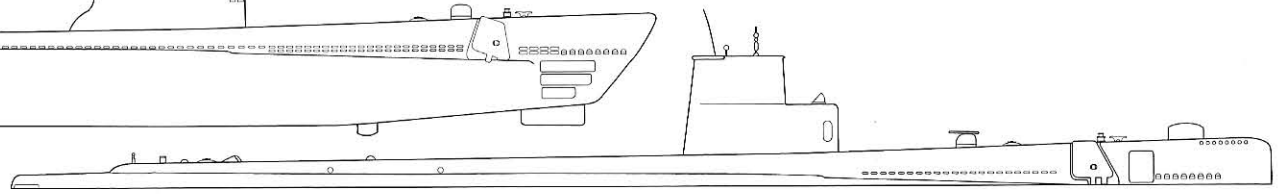
▲ *Sand Lance* (SS 213), February1945



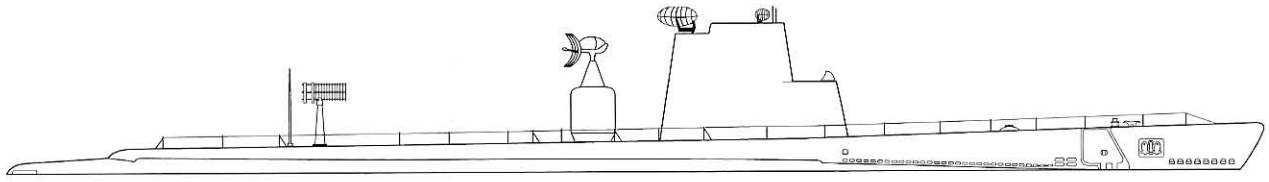
▲ *Sea Cat* (SS 389), 1951
Gunboat Conversion



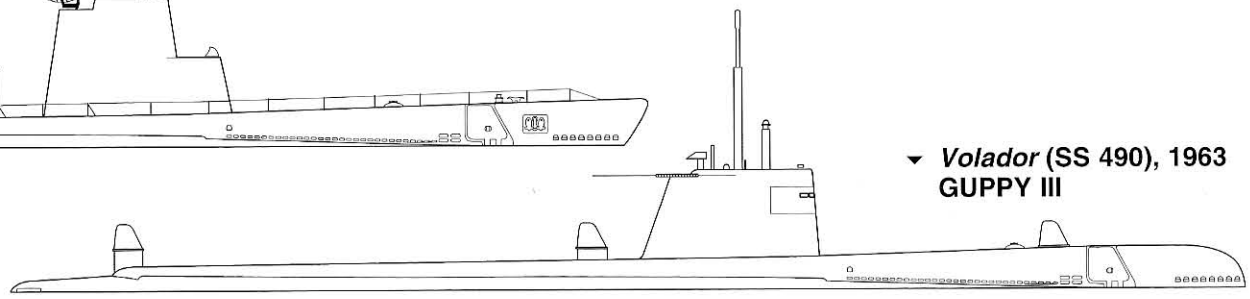
▲ *Torsk* (SS 423), September 1965
Fleet Snorkel Conversion



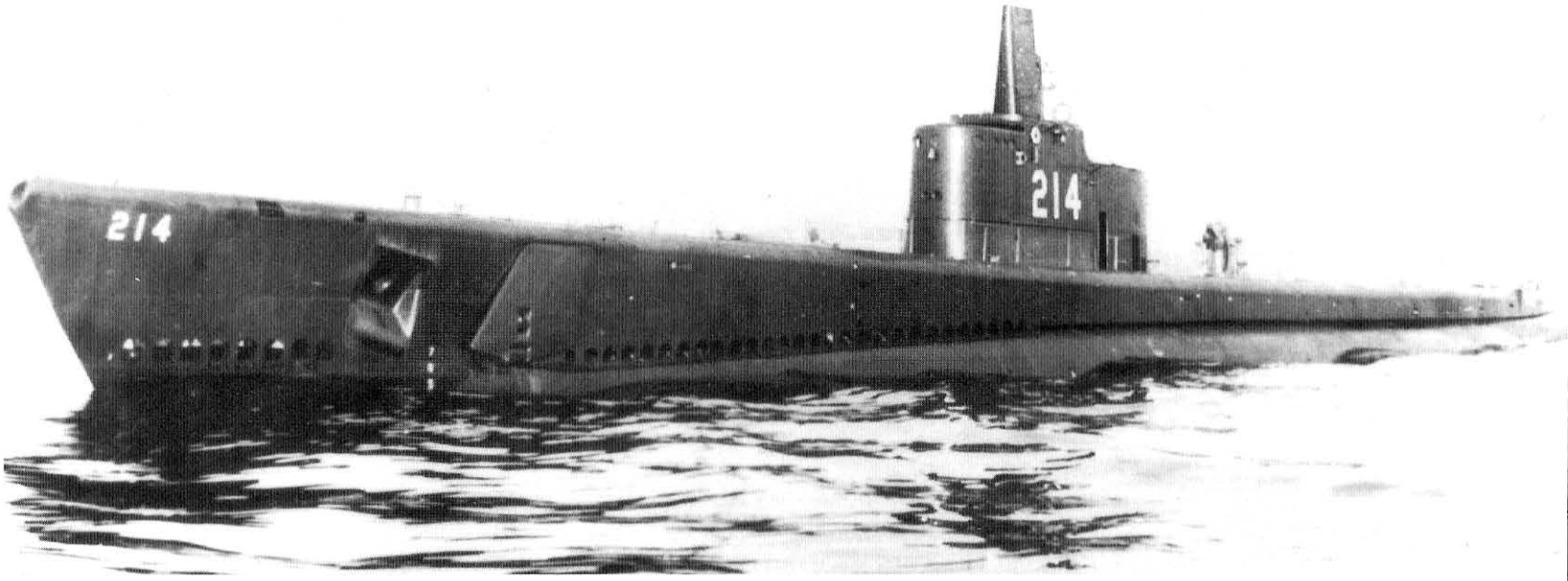
▲ *Bream* (SSK 243), 1956



▲ *Ray* (SSR 271), 1952
MIGRAINE III Conversion



▼ *Volador* (SS 490), 1963
GUPPY III



Just a few weeks away from her commissioning, *Grouper* (SS 214) sat for this portrait on 24 January 1942. Her anchor is missing, but she otherwise appears to be complete. The practice of painting hull numbers on the tower and bow (and the boat's name at the stern) was soon discontinued, but it was resumed almost as soon as the war was over. (SFL)

The *Gato* Sub-Class

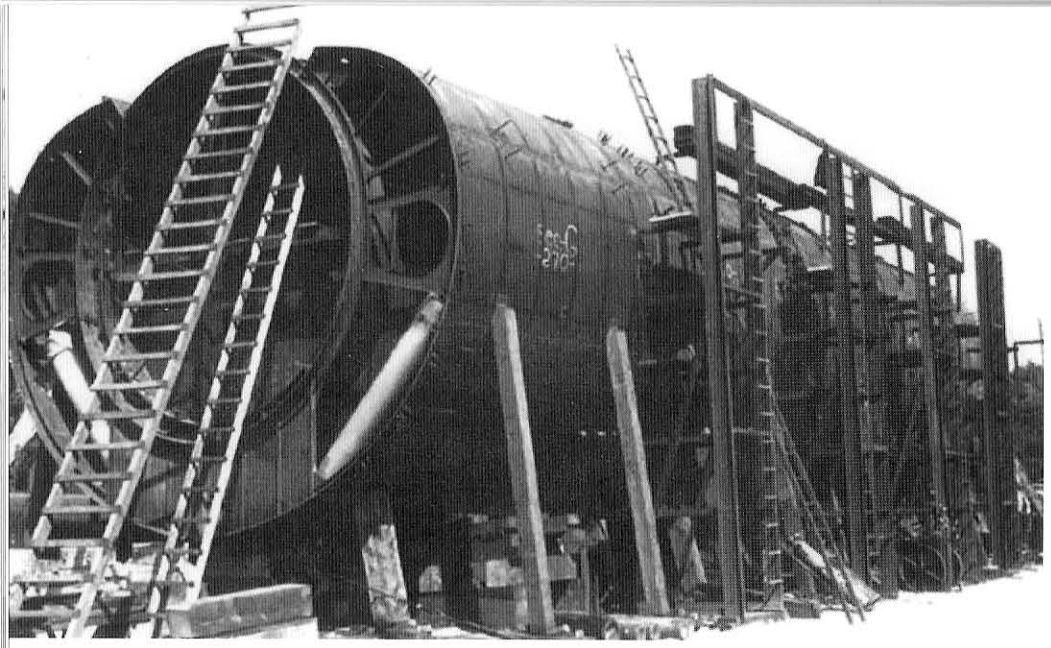
In the *Gato* class, the U.S. Navy had found a fully capable boat with the characteristics necessary to fight a war in the Pacific. In the wake of the Pearl Harbor attack, it was obvious that the only way to halt the rapid expansion of Japanese conquests would be with an unconventional strategy, and to their credit, Admirals King and Nimitz came up with exactly the right approach. They devised a dual strategy – containment around the edges and strikes deep into the heart of the Japanese Empire. The resources available were a small and terribly vulnerable force of aircraft carriers and three-dozen fleet submarines plus the nine old V-boats and a few more obsolescent S-class boats.

The containment was achieved by the aircraft carriers, which were deployed with courage and skill and turned back the Japanese at Coral Sea and decisively at Midway. (The argument has been made with some persuasiveness that those reverses were inevitable, the result of serious overextension of Japanese resources, and that almost any American strategy would have eventually led to the same result, but the boldness of Nimitz and the skill of Fletcher and Spruance advanced the final decision by years and saved countless lives.)

The deep strikes were achieved almost exclusively by American submarines. With the exception of the Doolittle raid of April 1942, American aircraft carriers were kept mainly on the periphery of the Japanese advance well into 1943. From the first days of the war, American submarines penetrated far into Japanese waters and exacted a steady toll of enemy shipping. At first that toll was smaller than it should have been for a number of reasons. One reason was the necessary learning curve as submarine commanders shook off the cautious habits of peacetime. Some never made the transition and were replaced; others adapted brilliantly. Another was the unreliability of torpedoes, which often failed to explode or ran erratically. Finally, there simply weren't enough boats to sustain a massive assault on enemy lifelines. Forty-odd boats, some ten or more years old, were nowhere near enough.

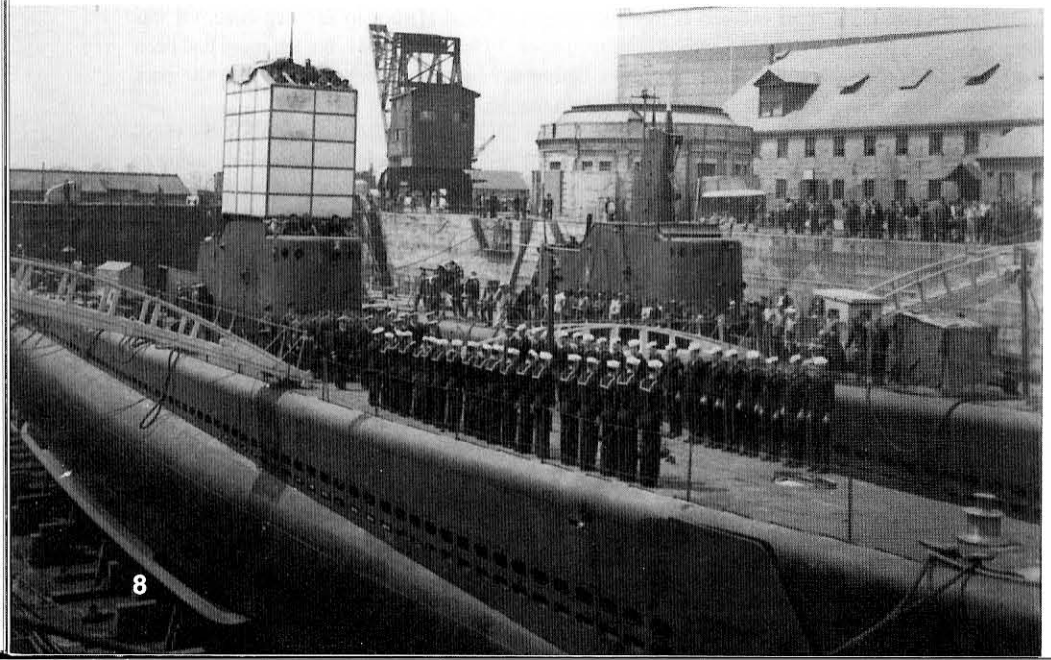
This last problem, at least, was well in hand. After the initial 1941 budget authorization of six boats of the new *Gato*-class, events had conspired to dramatically increase that number. The fall of France to Nazi Germany was a wake-up call to U.S. legislators, and President Roosevelt finally had the money and authority to fill the available building slips with keels and more to follow when those were launched. On 20 May 1940, twenty-two more submarines were added to the initial six, followed by an additional forty-three on 16 August. These orders went out to the experienced Electric Boat Company (forty-one boats), Portsmouth Naval Shipyard (fourteen boats) and Mare Island Naval Shipyard (six boats), and to one newcomer to submarine construction, Manitowoc Shipbuilding Company (ten boats). When it was realized that Mare Island would have two free slips towards the end of this cycle, two more hulls were added to the order in April 1941. This brought the total number of *Gato*-class boats ordered before the attack on Pearl Harbor to seventy-three. Of this number, only one, *Drum* (SS 228), was in commission on 7 December 1941, but ten more had been launched and fully twenty-one more laid down before the Japanese attacked. After that the pace accelerated. There would soon be enough boats to do the job.

The seventy-three *Gatos* were assigned hull numbers SS 212 (USS *Gato*) through SS 284 (USS *Tullibee*). Unlike other navies that identified ships with pennant numbers that could be randomly changed, the Navy assigned permanent hull numbers, which used an alphabetic prefix indicating type, most often but not always two letters, and a number indicating sequence within type. Hull numbers were assigned in blocks to a particular builder when the boats were ordered. Hull numbers SS 212-227 comprised the original order from Electric Boat, while SS 228-235 were ordered at the same time from Portsmouth. These numbers did not reflect in any way the order in which boats were started or completed. It wasn't unusual that *Drum* (SS 228) was started and completed before *Gato* (SS 212). The numbers assigned to boats that were cancelled generally weren't reassigned. Even though the highest numbered *Gato* actually completed was *Grenadier* (SS 525), numerous boats in the final wartime orders were cancelled, some with lower hull numbers and others with numbers all the way up to SS 562. Thus the first postwar attack submarines built by the Navy were the six boats of the *Tang*-class that started with hull number SS 563. If a boat changed role, she might have her hull number prefix changed, but not the sequence number itself. Thus, when *Cavalla* (SS 244) was rebuilt as a hunter-killer boat in 1952, she emerged as SSK 244. (▸▸ 8)



▲ **A section of a *Gato*-class boat, *Raton* (SS 270), being completed in the open air at Manitowoc on 12 July 1942 before it is moved into the final assembly shed. The circular inner hull (the pressure hull), is almost completely surrounded by the outer hull containing ballast, trim, and fuel tanks. The deck casing has not yet been fitted on top of the hulls. (Wisconsin Maritime Museum)**

▼ **Commissioning of *Herring* (SS 233) in the drydock at Portsmouth, New Hampshire, 4 May 1942. The full row of limber holes along the side of the hull distinguished boats built to the government design from those built to the Electric Boat Company design. There were also differences in the size and shape of the bow planes. The scaffolding above the tower protects ongoing work from the elements. (NARA)**



The *Gatos* differed from the preceding *Tambors* only in minor details. The *Gatos* were 51 tons heavier and 4 feet 6 in (1.4 m) longer. The extra length went into the planned installation of larger, more powerful diesels and the addition of a watertight bulkhead between the two engine rooms. However, the new diesels weren't ready in time to be installed in any of the first-generation *Gatos*, and the engines actually installed were in fact the same size as those in the *Tambors*. This had no effect on the boats' speed, since the diesel-electric propulsion scheme didn't directly connect the diesels to the propeller shafts. The critical factor was the electric motors, which were also the same size in *Gatos* as in the *Tambors*. However, the extra length of the *Gatos* made the hull form slightly more efficient, giving them a half-knot more speed on the surface (21 knots). That and improved, more powerful batteries also gave them a quarter-knot more submerged speed (9 knots). This greater efficiency and the increased length, which allowed fuel oil capacity to rise to 94,000 gallons (355,829 l), increased the range to 12,000 nautical miles at 10 knots. As a result of testing *Tambor* with live depth charges, internal fittings in the *Gato*-class were improved, and the test depth was increased by 50 feet (15.24 m) to 300 feet (91.44 m). The calculated crush depth remained the same at 500 feet (152.4 m). (The test depth was the depth to which a boat would be tested as part of her acceptance trials. She was expected to reach that depth without any leaks or pressure-related failures. In wartime, the test depth was regularly exceeded by captains trying to evade depth charging. The crush depth is the theoretical limit below which the hull would collapse.)

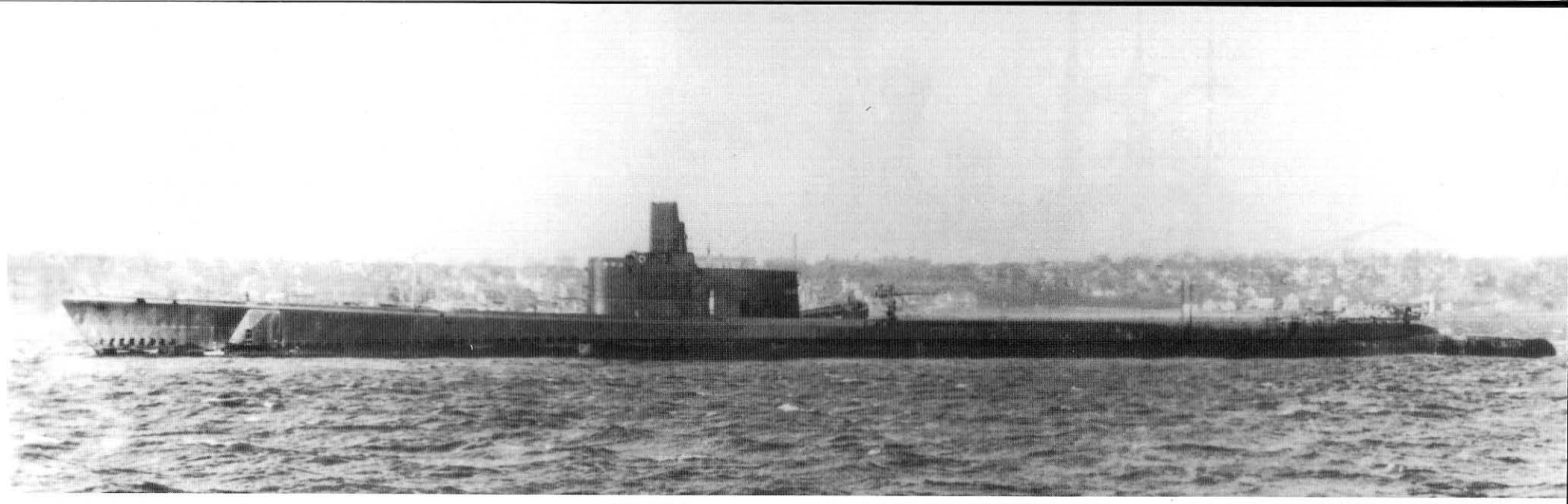
The interior of a *Gato*-class submarine was divided into nine watertight compartments. From the bow, these were:

Forward Torpedo Room. This was the site of the six forward torpedo tubes, four of which were visible above the deck plates. The other two could only be reached by removing the deck plates. At the start of a patrol, there would be one torpedo in each tube, one reload each for the two lower tubes stored below the deck plates, and two reloads for each of the four upper tubes – a total of sixteen torpedoes. The sonar gear was raised and lowered and/or rotated from this compartment, as was the pitometer log. Fourteen bunks for crewmen were also found in this compartment.

Forward Battery Compartment. Half of the boat's 252 battery cells were located below the deck plating of this compartment. Above this deck was 'officers' country,' the site of the wardroom where the officers ate, the pantry where their food was plated, and the three compartments where the officers berthed. One compartment was for three junior officers. The executive officer ('XO,' second-in-command) and first lieutenant (often a lieutenant commander) shared another compartment. The captain had his own compartment/office, the only private space on the boat. The five most senior chief petty officers (CPOs) shared a fourth compartment. If, as was often the case, there were more than the nominal complement of six officers — some boats went on patrol with as many as ten officers — this space got rather crowded. This compartment also contained the yeoman's office, where reports were prepared and the log maintained, and the officers' shower and head.

Control Room. This was the center of the boat, from which she was steered and her depth was controlled. The Hull Opening Indicator Panel, known as the 'Christmas Tree,' was located here. It got that name because there was a red and green light for every opening in the pressure hull, green indicating the opening was closed. (Hence the term 'green board,' meaning it was safe to dive the boat.) Flooding or blowing of all tanks was controlled from this compartment. Below this room was the pump room, where most of the boat's pumps and compressors were located. The radio shack was at the aft end of this compartment.

Conning Tower. This was a separate, relatively tiny cylindrical compartment located above the control room and housed within the boat's external tower structure. Both of the boat's periscopes were operated from the conning tower. The first *Gatos* had a Type 2 attack or 'needle' periscope (so-called because its head was very narrow in order to leave a minimal wake) and a Type 3 search periscope with a broader angle of view. Starting in 1944, a Type 4 'night' periscope replaced the



Type 3. The Type 4 had a larger head to admit more light, a shorter tube so that less light was dispersed, and incorporated the ST range-only radar to aid in making submerged night attacks. The Torpedo Data Computer (TDC) was on the port bulkhead aft. The displays for the surface search radar(s) and active sonar were located here, as was a secondary steering position. Repeaters for most of the primary gauges found in the control room were located here as well. When a submerged attack was being made, this was a very crowded space, as the captain, executive officer, one or two TDC operators, one or two radar/sonar operators, and a talker were all stationed here.

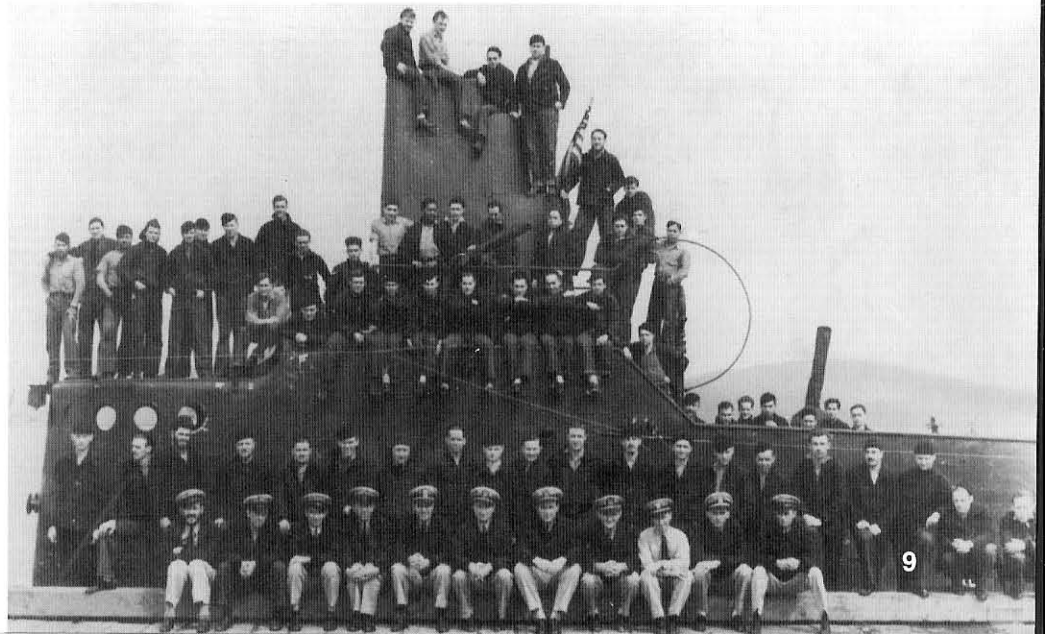
After Battery Compartment. The remaining 126 battery cells and the magazine were located here beneath the deck plating, as was the main pantry, freezer, and refrigerated food storage. Above this deck was located the medical locker, the crew's mess, the galley (where all food for officers and men was prepared), and thirty-six bunks. The crew's showers and head (a two-holer) were at the aft end of this compartment, as was the boat's washing machine and the tiny storage lockers where the crew could store valuables. This is the largest of the boat's compartments.

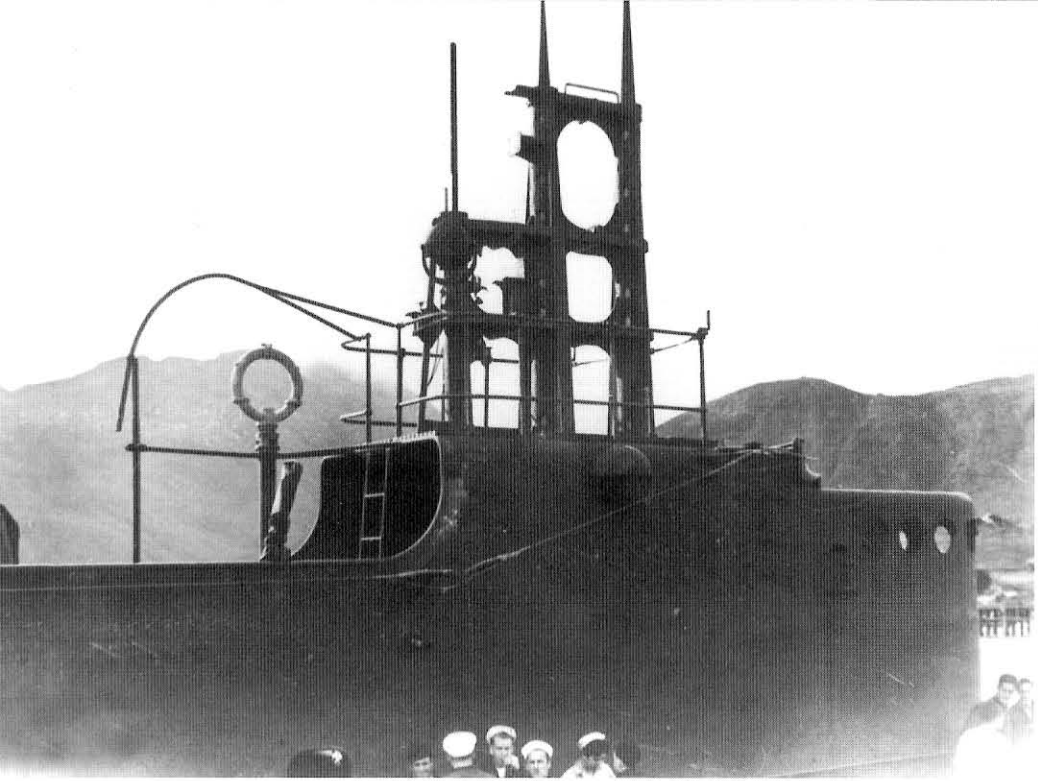
Forward and After Engine Rooms. These two compartments were basically identical. Each contained two of the four main diesel engines. Each diesel was connected to an 1,100 kilowatt electrical generator used to charge batteries and/or drive the electric motors as needed. The diesel engines found in *Gato*-class boats were 1,600 bhp two-cycle units made by General Motors (GM) or Fairbanks-Morse (F-M). The latter were license-built Junkers Jumo engines. (Two-cycle diesels incorporate a separate blower to clear exhaust from the cylinder. This makes them mechanically more complex than a four-cycle diesel and requires them to have a smaller cylinder with a longer piston stroke. The Navy liked two-cycle diesels in submarines because they ran cooler, but found out after the war they were much harder to run with a snorkel because they required a much greater air intake than the four-cycle engines used by the Germans and most other countries.) The GM engine was a V-16 Model 16-278 or 16-278A, each with two banks of eight cylinders, which ran at 750 rpm. The F-M engine was a Model 38D, available in nine- and ten-cylinder versions, both opposed-piston designs running at 720 rpm.

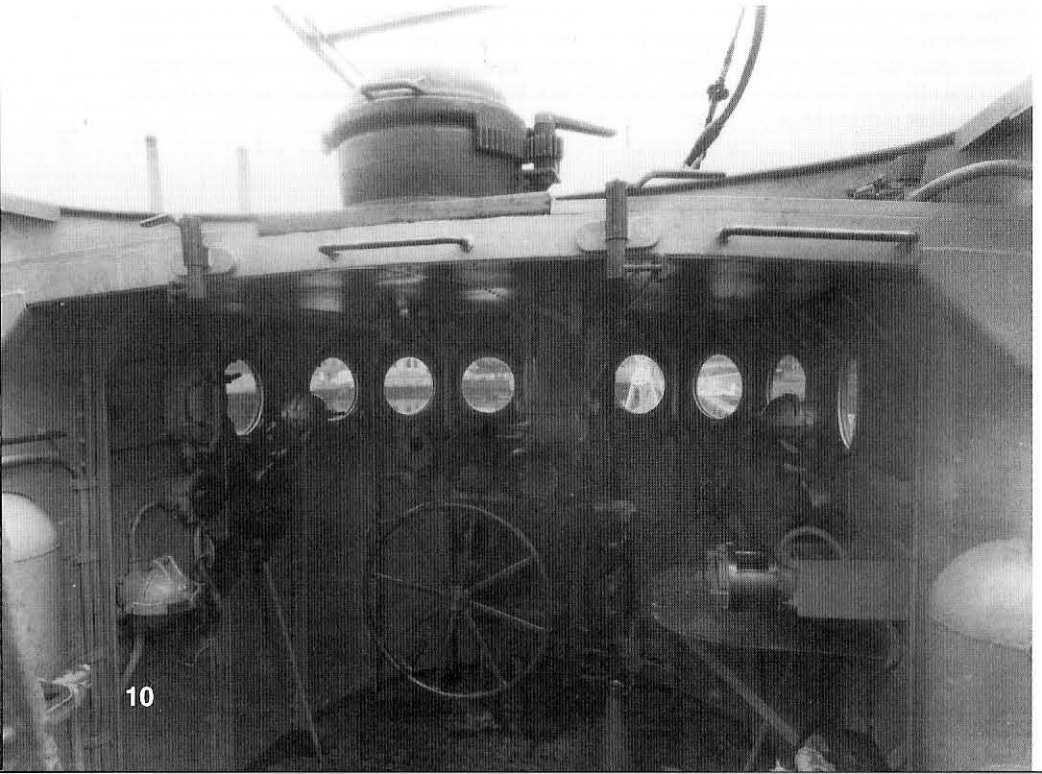
Maneuvering/Motor Room. The four electric motors of 1,350 hp each and the two sets of reduction gears that connected them to the propeller shafts were located below the decking. The switch panels that controlled the motors and gearboxes were located above the deck in the (⏩ 10)

▲ ***Growler*** **(SS 215) off Groton, Connecticut, on 21 February 1942, a month before her commissioning. She differs from the boats completed before her only in having no hull number or name. Otherwise, she has the 'as-designed' tower structure and a single 3-inch, 50-caliber deck gun as the only visible armament. She is painted in the pre-war gloss black color scheme. She became famous as the boat saved through Cmdr. Howard Gilmore's heroic self-sacrifice but was lost on her eleventh war patrol in October 1944. (NARA)**

▼ **The crew of *Finback* (SS 230), seen at Dutch Harbor on 1 August 1942 between missions in the Aleutians, poses on and in front of her tower. A .50-caliber machine gun is wrapped in a protective tarp on the cigarette deck. A similarly wrapped .30-caliber machine gun is located on the railing at the base of the periscope shears. The circular wire structure to the left of the .50-caliber gun protects the direction-finding (DF) loop antenna. (SFL)**







◂ The first of the wartime modifications to the basic structure of the *Gatos* was the removal of the plating around the periscope shears. This plating trapped air and slowed the diving of the boat. It also was very visible from a distance; the open shears proved to be much harder to see at the horizon. This view shows the name boat, *Gato* (SS 212) in mid-1942. (SFL)

maneuvering room. The electric motors ran most efficiently at a constant, high speed. The speed of the boat was controlled by changing the gearing in the Westinghouse gearboxes, in much the same way that an automotive transmission functions.

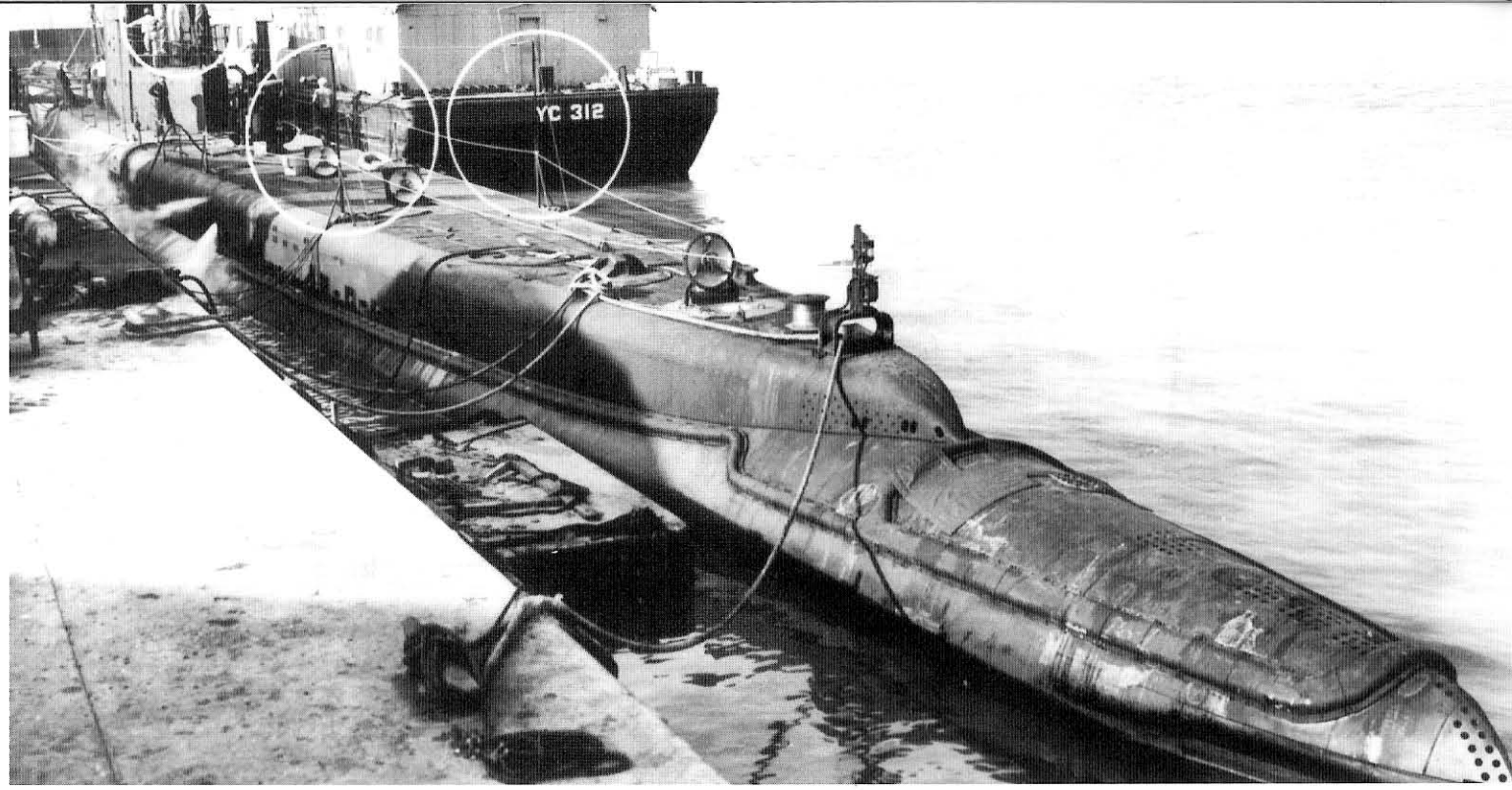
After Torpedo Room. This compartment housed the remaining four torpedo tubes and eight torpedoes, four in the tubes and four reloads on skids, one for each tube. It also contained fifteen more bunks for crew berths and the bosun's tool locker. That totalled seventy bunks, not counting officers' berths, or one bunk for each of the nominal wartime enlisted crew, but several factors contributed to cause 'hot bunking,' in which three men shared two bunks. One factor was that the crew was often larger than expected. By war's end, the enlisted complement often exceeded eighty men. Also, some bunks in the torpedo rooms couldn't be lowered until some of the reloads had been moved into the tubes and, as the war progressed and targets became fewer, some boats went an entire patrol without firing off a full load of torpedoes.

The *Gatos* were double-hulled boats, meaning that the pressure hull was surrounded by a second non-watertight hull containing the boat's various ballast, trim, and fuel tanks. The central section of the pressure hull was an externally-framed cylindrical structure constructed of 7/16-inch (14.3 mm), 27.5-pound (12.5 kg) untreated steel. The two end compartments were truncated conical sections, and the conning tower was a smaller cylinder fitted on top of the main pressure hull above the control room. The maximum diameter of the pressure hull was 16 feet (4.9 m).

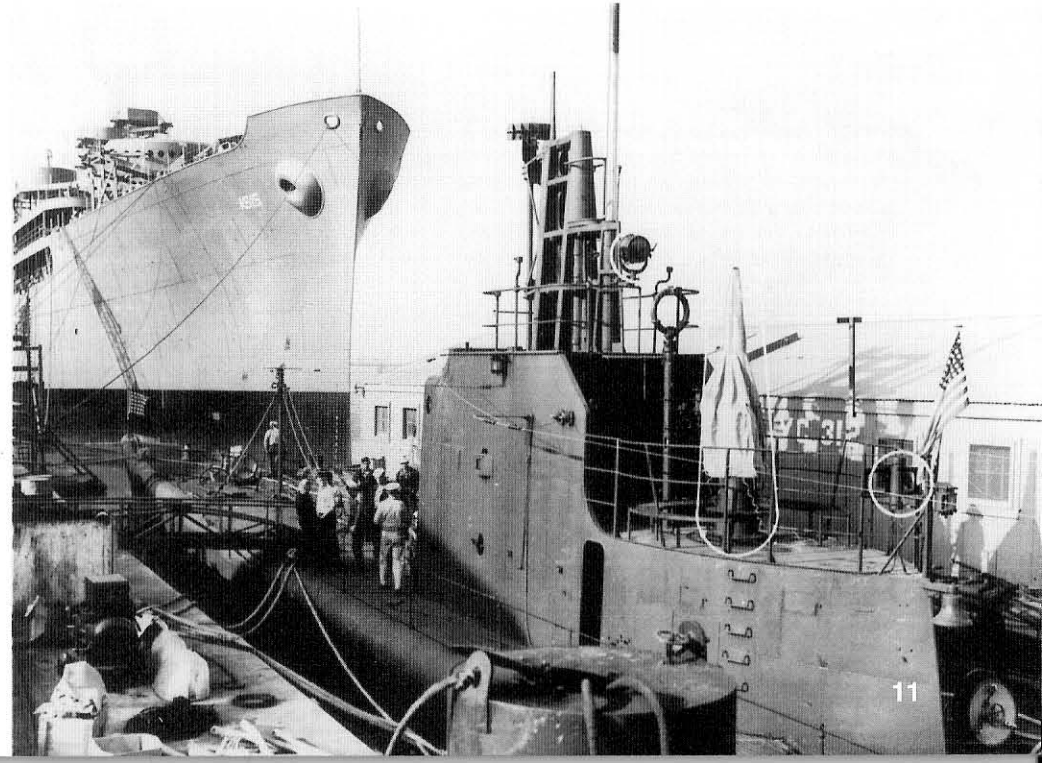
On top of the outer hull was an external superstructure. This included the deck casing that gave the boat a shape that allowed high surface speed. Forward, the deck casing housed the boat's anchor and capstan, the forward dive planes, and a buoyancy tank. The deck was strengthened forward and aft of the bridge to allow the installation of two 3-inch, 50-caliber (76.2 mm) deck guns, though in practice only one was ever carried. This deck casing trapped air as the boat submerged and accounted in part for the relative slowness with which American submarines dived. This was counteracted in part by the addition of limber holes in the side of the superstructure. The conning tower was enclosed in an external tower or fairwater structure that included an enclosed bridge with a conning station. An open area aft, known to the crew as the 'cigarette deck' for obvious reasons, had a pintle mount for a Browning .30-caliber (7.62 mm) or Browning .50-caliber (12.7 mm) machine gun for anti-aircraft protection. (The machine gun had to be brought inside when the boat submerged.) There were minor differences in appearance between the boats built by Electric Boat (and Manitowoc, which got its drawings from Electric Boat) and those built at the government-run navy yards. The most obvious initial difference was in the pattern of limber holes, which were more numerous and extended further aft from the bow in government-built boats. As the war progressed, the tower structure of new and refitted boats was cut down and modified to carry more armament and antennae, and the number and pattern of limber holes in the superstructure varied greatly. It is safe to say that, while boats from the three sub-classes of *Gatos* were often indistinguishable, no two boats were absolutely identical in appearance.

All seventy-three *Gatos* saw combat. Of the ten most successful American submarines in terms of tonnage sunk, eight were from this sub-class. Nineteen were lost during the war. (▸▸ 23)

◂ The covered conn protected the helmsman from bad weather but proved to be redundant in wartime, as there was a secondary helm inside the conning tower to which orders could easily be passed, and the watch and officers on the tower needed to be out in the open to get maximum visibility. This is the conn on *Dolphin* (SS 169), an earlier boat launched in 1932, but the first *Gatos* had a similar helmsman's position. (USN)

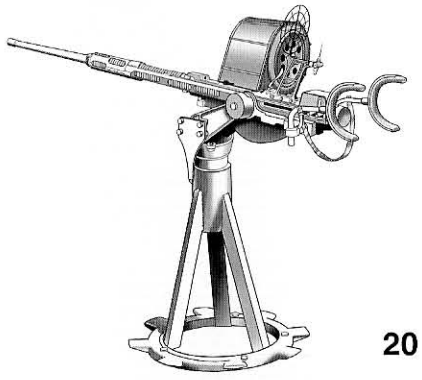


▸ *Sunfish* (SS 281) shows some of the changes being made to new and refitted *Gatos* as war experience accumulated in 1942. These views, taken at Mare Island Naval Shipyard, California, on 24 October 1942, show the boat as post-shakedown repairs were completed just before she set out for Pearl Harbor and her first patrol. This view of her stern shows degaussing cables that were added during her construction; later *Gatos* had these removed or relocated. (NARA)

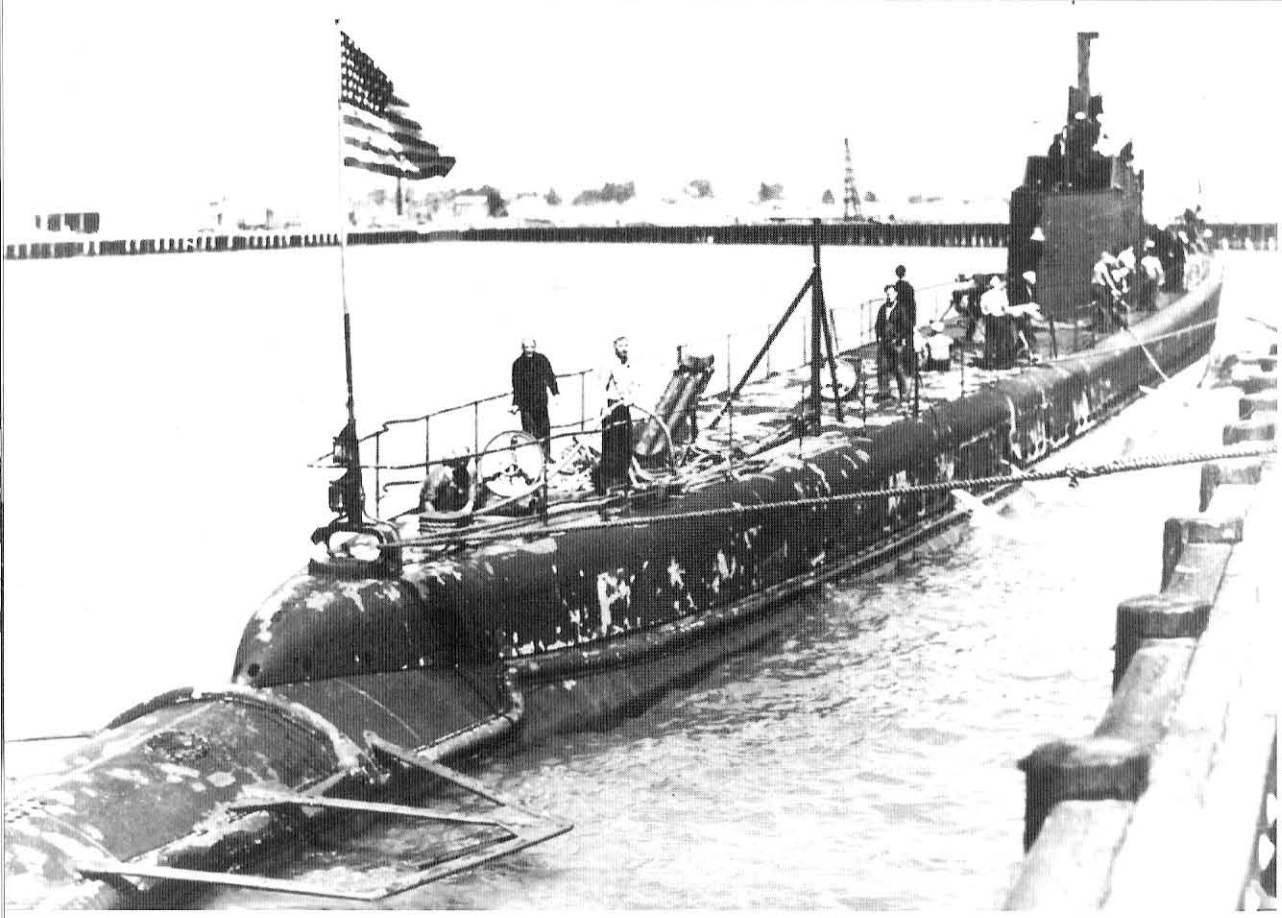


▸ The most obvious changes to *Sunfish* were to her tower, which was cut down aft to make room for a larger anti-aircraft gun. Under the canvas cover is a 20 mm Oerlikon mount. Also, the first-generation of the wartime sensor suite has appeared — an early SJ surface-search antenna on a short mast in front of the periscopes and an SD air-search antenna on an extendable mast that replaced the shortwave antenna aft of the periscopes. (NARA)

Anti-Aircraft Weapons

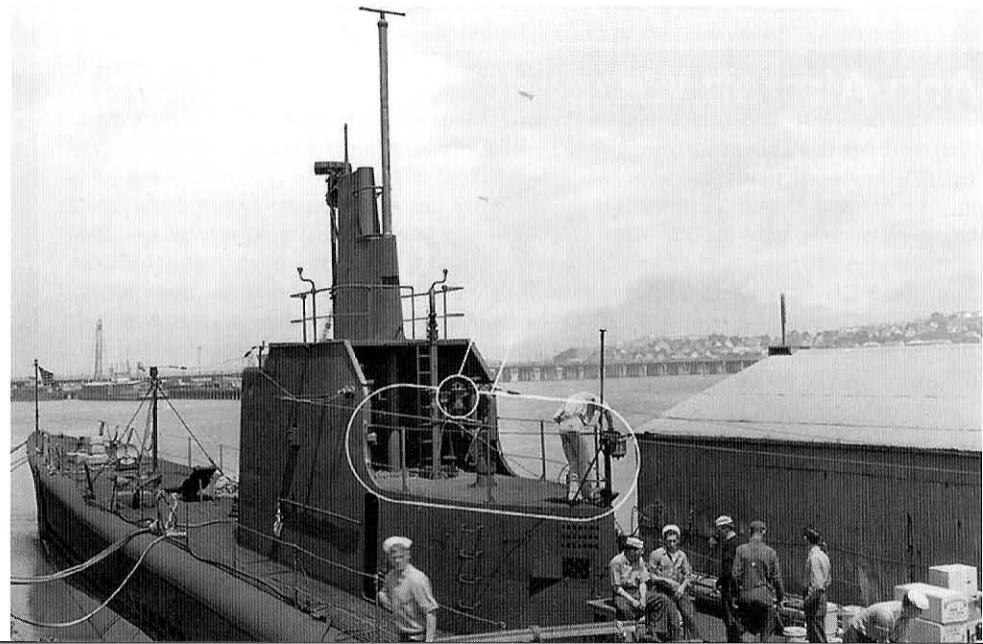


20 mm Oerlikon Mount



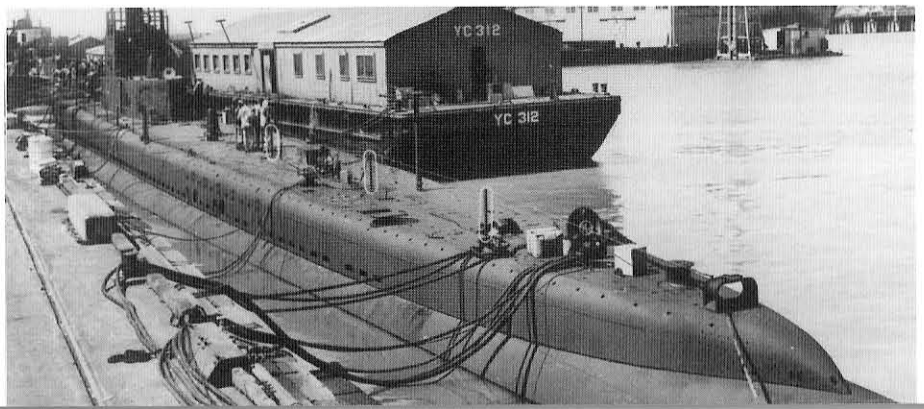
Probably the most famous of the early *Gatos* was *Wahoo* (SS 238). After a couple of disappointing patrols, she was taken over by the aggressive Lt. Cmdr. Dudley W. 'Mush' Morton, who with his executive officer, Lt. Dick O'Kane, led *Wahoo* on a string of highly successful missions. In this view of *Wahoo*, before her first patrol, she's alongside at Alameda on 2 August 1942, in great need of a paint job. Her tower is in 'as-built' form, but she does have the early-war radar suite. Besides the degaussing cable aft, she also has an added guard protecting her aft planes and screws. Her after torpedo hatch is open, and the chute used to load torpedoes through the hatch has been erected. (USN)

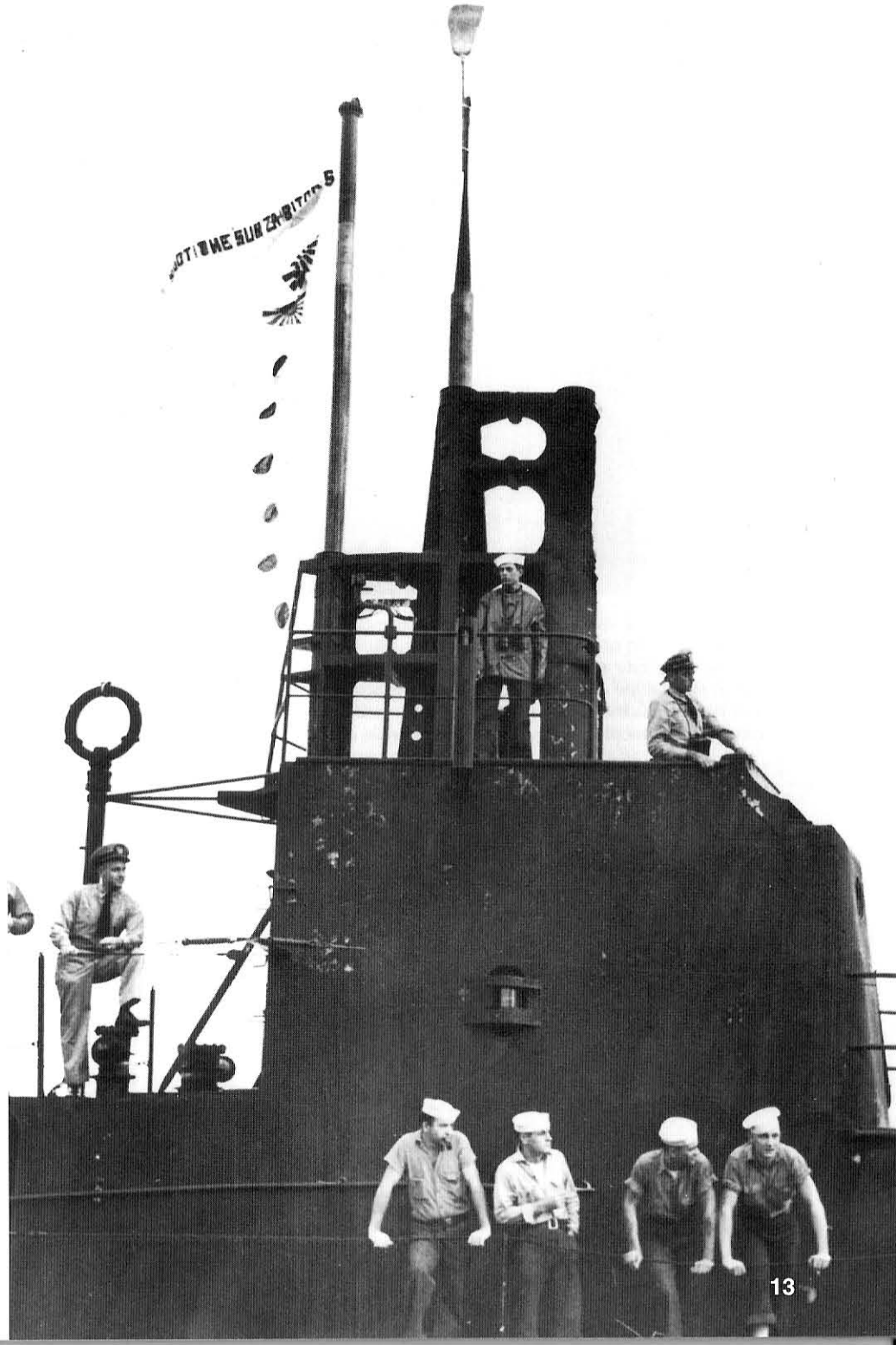
Barely eight days later, *Wahoo* looks rather different. She's been taken in hand by Mare Island, and her tower has been cut down aft. She also has been painted in a fresh coat of overall dull black (Measure 9), the standard early war camouflage. It was not considered as effective as an overall dark blue system that was tried out in early 1941, but the blue paint deteriorated rapidly, while the black paint kept its tone for many months and was therefore adopted as the standard. (NARA)

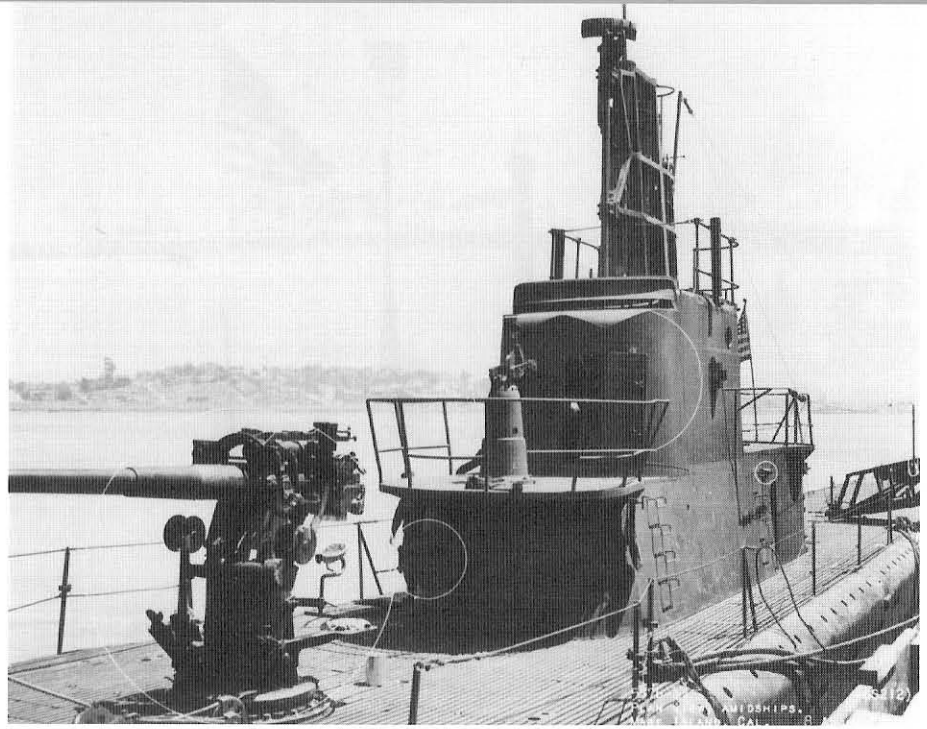


▸ In October 1942, before her second patrol, *Wahoo* had another brief refit at Pearl Harbor, during which her tower was cut down forward and two single 20 mm Oerlikon mounts were fitted. A 4-inch, 50-caliber deck gun replaced the 3-inch gun forward. After that refit, she set out for the Solomons and then went on to Brisbane. There, Morton relieved the first captain, and *Wahoo*'s fortunes changed dramatically. This view shows *Wahoo* entering Pearl Harbor on 7 February 1943, at the conclusion of Morton's first patrol in command of the boat. Eight small Japanese flags — two 'rising sun' flags indicating military victims and six 'meatballs' indicating merchant sinkings — fly from the radar mast, indicating the cumulative record of *Wahoo*'s claimed sinkings in three patrols, five of the eight coming on this third patrol. (As was typical in all navies, these claims were rather exaggerated; in fact, *Wahoo* had sunk only four ships, three of them on her just-completed third patrol.) A broom lashed to the number two periscope indicates a clean sweep. The pennant flying from the SD mast reads "SHOOT THE SUN ZA BITCHES," a reference to an incident on 26 January, when Morton ordered lifeboats full of Japanese soldiers shot up, rather than let them live to fight another day. In this heavily censored photograph — both her SD antenna and the entire mast and antenna for the SJ forward of the periscopes have been 'whited out' — Morton can be seen on the bridge and O'Kane on the aft cigarette deck in front of the DF loop. (NARA)

▾ In May, after her third successful patrol under Morton, *Wahoo* was sent back to Mare Island for a major refit. These two views from the end of that yard period, taken in mid-July 1943, show a typical mid-war fit of weapons and electronics, unusual only in that Morton requested and was given a third 20 mm mount located on the hard point aft of the tower. Otherwise, except for the removal of the degaussing cables and propeller guards and the proliferation of limber holes along the deck edge, she looks little different from her appearance at Pearl Harbor six months earlier. The circular opening on her deck on the portside aft is a well for marker buoys, to be released if the boat was unable to surface. (NARA)





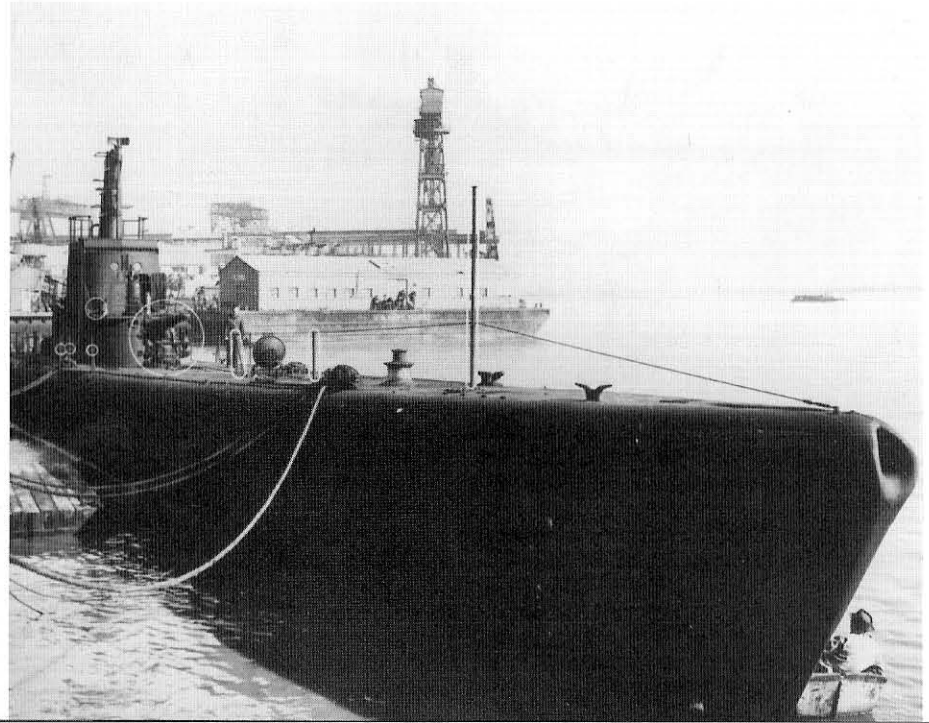


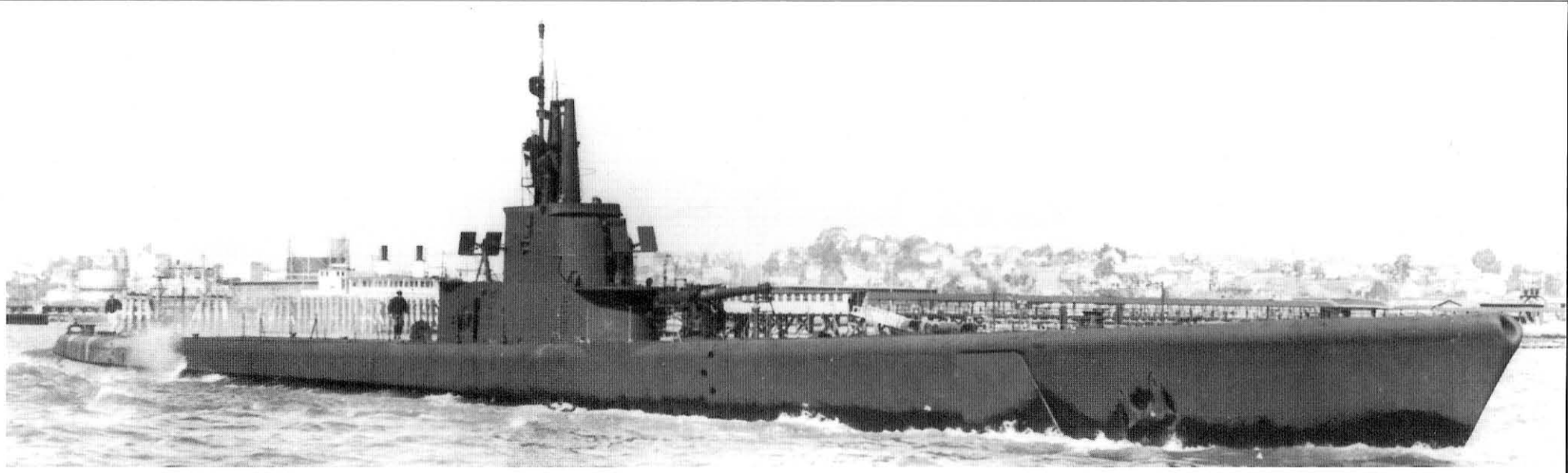
▲ Seen on 8 August 1943 at Mare Island, *Gato* demonstrates well that no two *Gatos* had exactly the same pattern of limber holes, tower structure, armament, and electronics. There were multiple variations among the early boats in even such minor details as the wind-deflecting venturi plate at the edge of the bridge and the shape of the bridge front. Another difference from *Wahoo* was the size of the cigarette deck platforms. As the war went on and bigger guns were fitted, larger platforms with more noticeable overhangs were needed. (NARA)

▼ This photograph of *Dorado* (SS-248), being finished at the Electric Boat yard in August 1943, shows a tower similar in form to *Gato's*. One noticeable difference is the absence of limber holes at the deck edge on *Dorado*. Electric Boat, as with most defense industries, employed quite a few 'Rosies,' two of whom can be seen in the foreground. (NARA)

▲ *Kingfish* (SS-234) underwent extensive reconstruction in early-1943 after being severely damaged by depth charges on her third patrol off Formosa. She is seen here as she appeared at the end of that yard period on 7 June. (NARA)

▼ For the most part *Kingfish*'s appearance is typical of the period except for the presence of two portholes on the front face of her bridge structure, an apparently anachronistic note. (NARA)

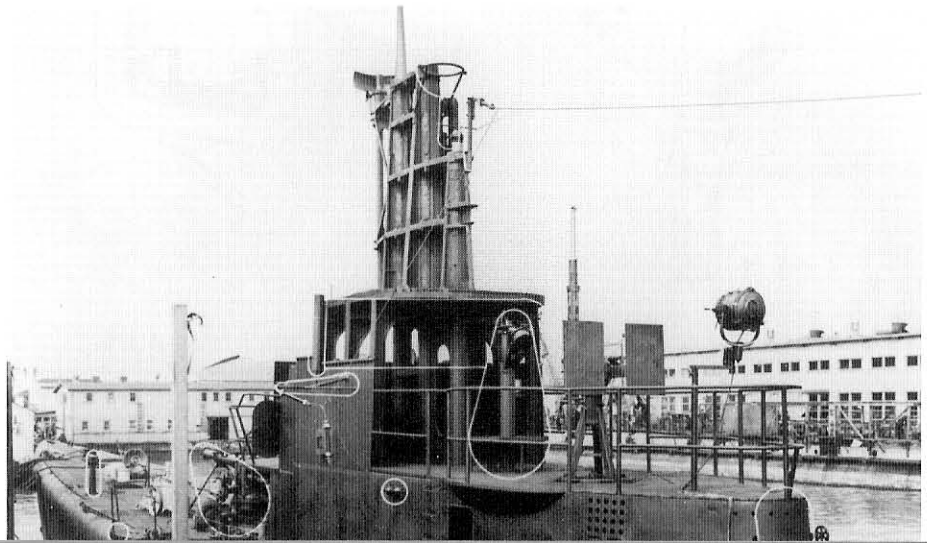


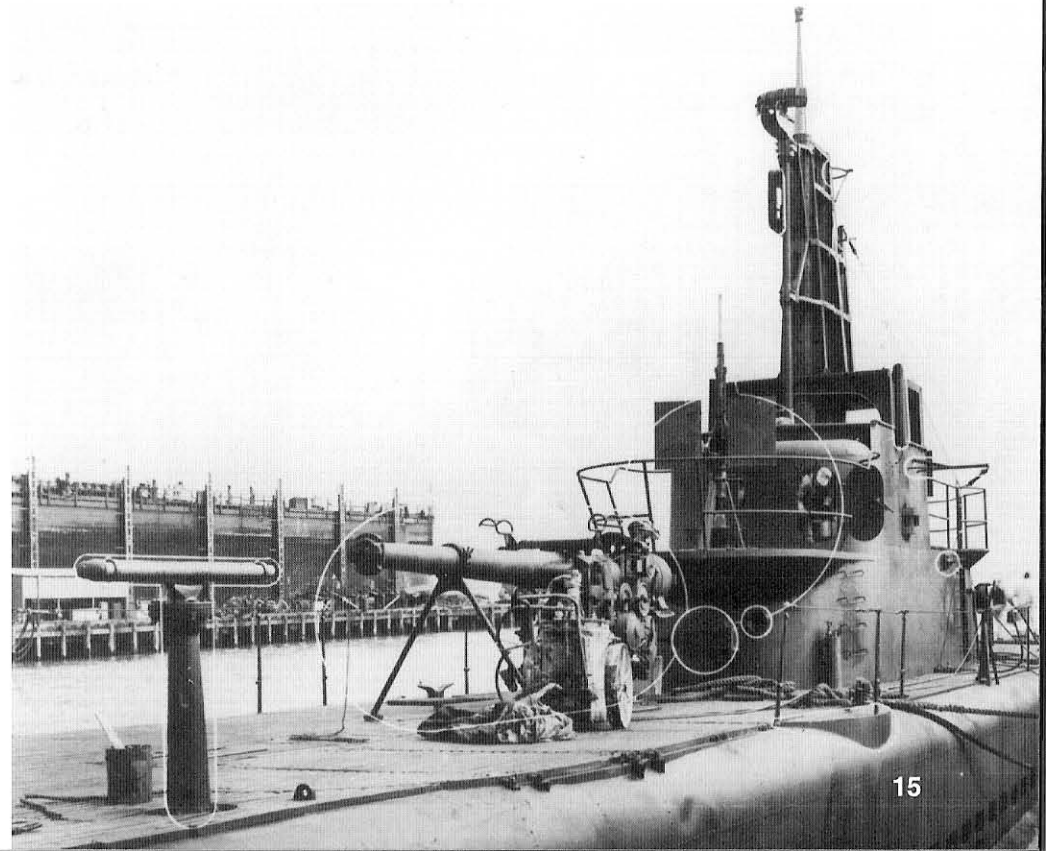


▲ Trimmed down somewhat by the bow, *Harder* (SS 257) begins her post-refit trials, 19 February 1944. She is in completely typical mid-war form, with a 4-inch, 50-caliber deck gun, a pair of 20 mm mounts on her tower, and the SD and SJ radar antennas, both located aft of the periscopes. An unusual feature is the presence of shields for the Oerlikons, which must have caused considerable drag underwater. She is painted in the still-standard Measure 9 overall black scheme. She appears to have no extra limber holes, also rather unusual. *Harder* was very successful, particularly at sinking Japanese destroyers, claiming four in her career. She was lost on her sixth patrol in August 1944. (NARA)

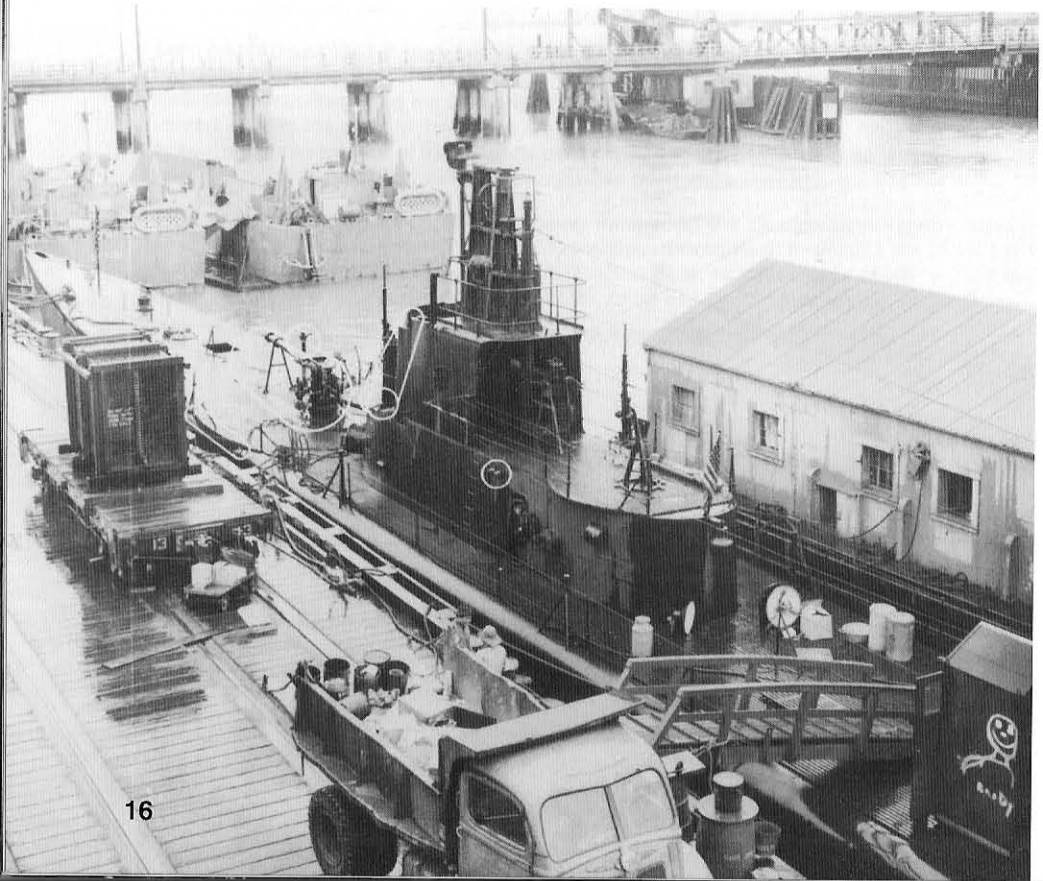
▶ The next step in tower evolution was the cutting down of the high tower plating typical of the *Gato*-subclass, whether built with the original tower design or with the mid-war version already incorporating fore and aft cigarette decks. These views show *Shad* (SS 235) after completing a refit at Hunter's Point Naval Shipyard, San Francisco, 6 March 1944. A T-shaped JP line array sonar head has been installed on the deck forward of the 4-inch, 50-caliber gun. The squared DF loop on the starboard side of the shears is unusual. (NARA)

▼ *Shad* has the unusually long after cigarette deck typical of early-war boats. When the tower plating was cut down, the framing for the higher tower structure was left to support positions for lookouts, the railings for which have apparently not yet been added. A Target Bearing Transmitter (TBT — a surface attack torpedo aiming device) has been added on the aft cigarette deck forward of the Oerlikon mount. (NARA)



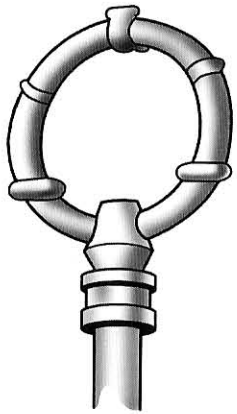


▲ Many early *Gatos* can be distinguished from those built later by the length of their tower structure. This view of *Drum* (SS 228), the first *Gato*-class boat commissioned into the Navy, shows the unusual length of her tower, extending well aft of the Oerlikon mount, which is itself well clear of the periscopes. Seen from the side, *Drum* appears to have unusually tall periscope shears, but this is an illusion caused by her tower plating being cut away, (SFL)

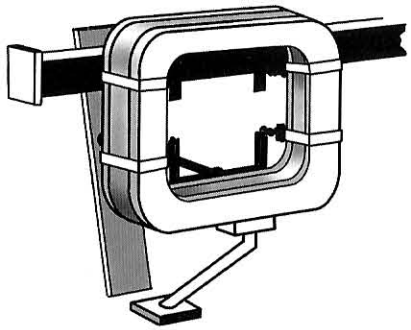


DF Loop Antennas

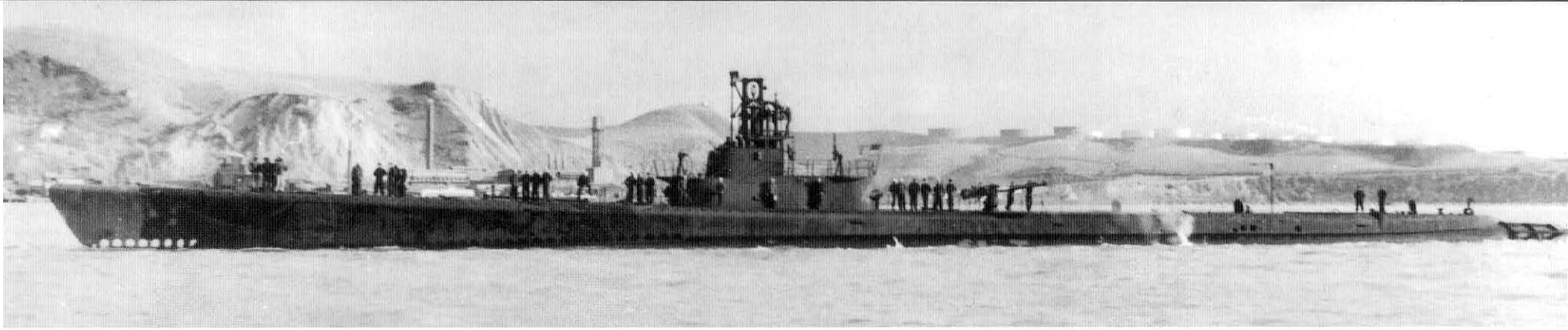
Round loop



Square loop

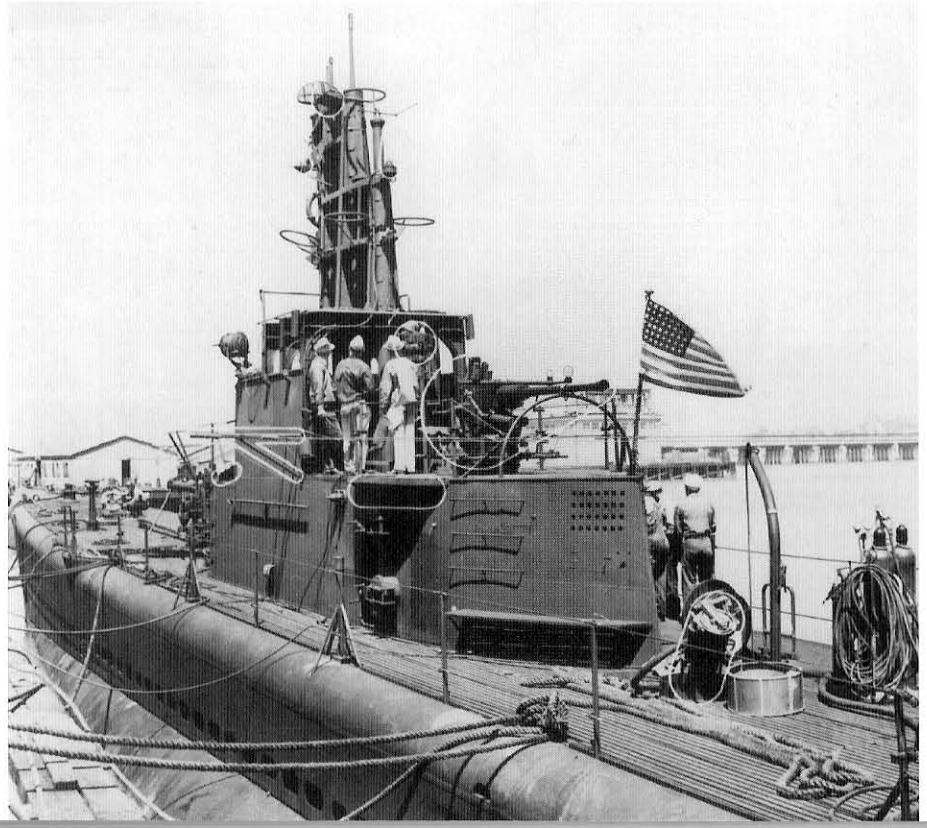


◀ Proving again that no two *Gatos* looked alike, *Mingo* (SS 261), a mid-war boat, seen at Mare Island on 2 February 1944, has not had her tower plating cut down. She does have the shorter aft cigarette deck typical of boats built with the two decks in place. She also has a JP sonar head just forward and starboard of the deck gun. (NARA)

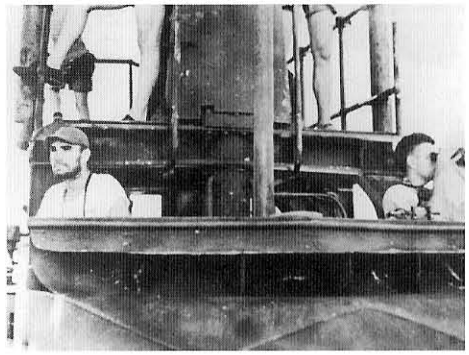


▲ Lt. Cmdr. James Blanchard took over *Albacore* (SS 218) after her seventh patrol in December 1943. After one more patrol, he brought her to Mare Island for a much needed refit. She emerged as seen here on 28 April 1944, with features typical of that time in the war, including the cut-down tower plating. (NARA)

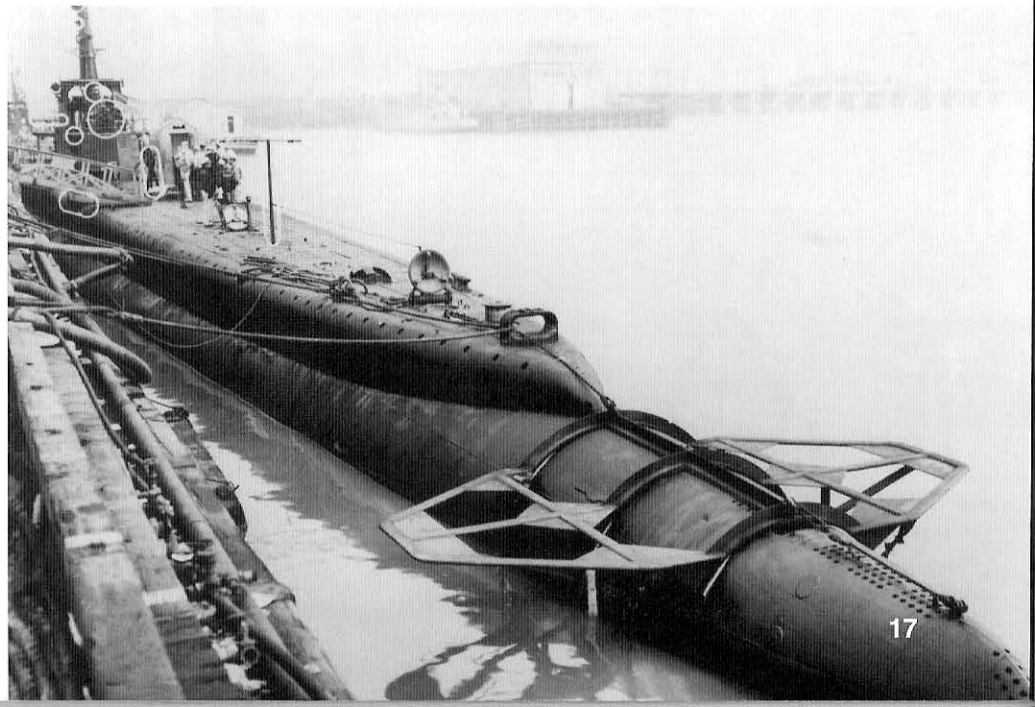
▼ *Silversides* (SS 236), one of a famous trio of boats built alongside each other at Mare Island that also included *Wahoo* and *Trigger,* returned to that yard for a refit after her tenth patrol in June 1944. She is seen here on 21 August as she was completing that refit. Late war features are beginning to appear, such as the later, paraboloid SJ antenna, several stub antennas (one oriented horizontally left of the shears for the APR-1 radar detector, and one oriented vertically aft of the SD mast for IFF) and the 40 mm Bofors on the after cigarette deck. (NARA)



▶ Lt. Cmdr. Blanchard (with the beard and baseball cap) stands on the bridge of *Albacore* during a subsequent patrol. Three lookouts, wearing shorts, stand on the decking on top of the tower framing. *Albacore,* under Blanchard, went on to sink the Japanese carrier *Taiho* in June, but was lost on her tenth patrol in November. (SFL)

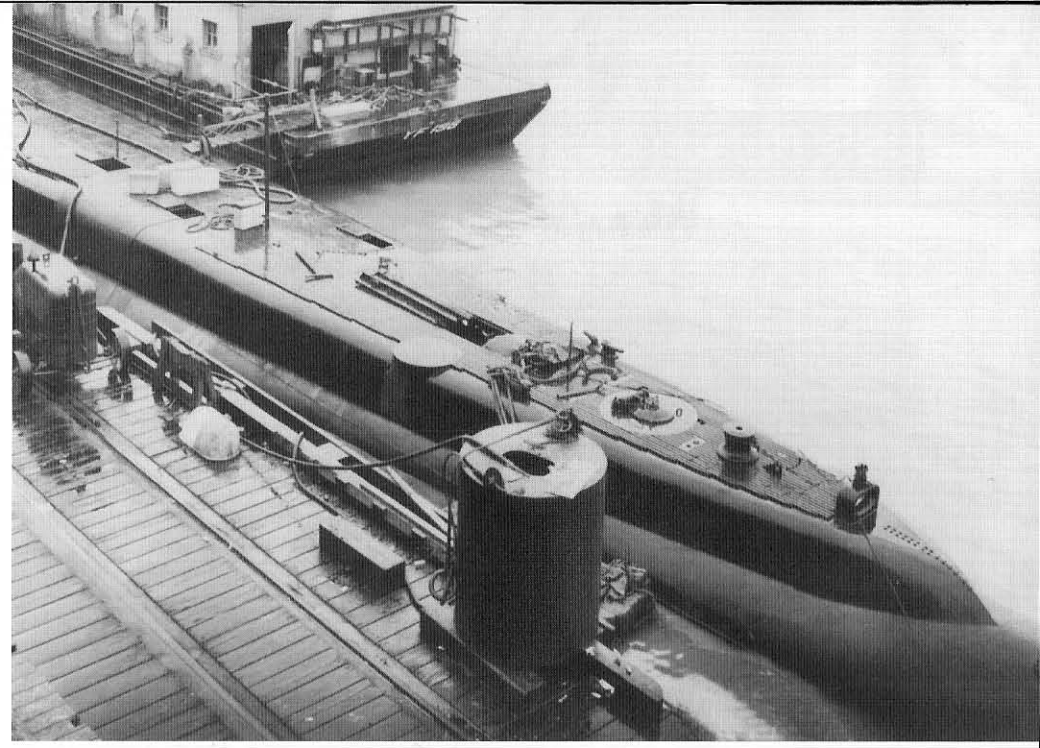


▼ *Silversides* shows off the temporary propeller guards that would be removed when she left the yard. She ended her war after successfully completing fourteen war patrols, ranked third in number of ships sunk and fifth in tonnage. (NARA)

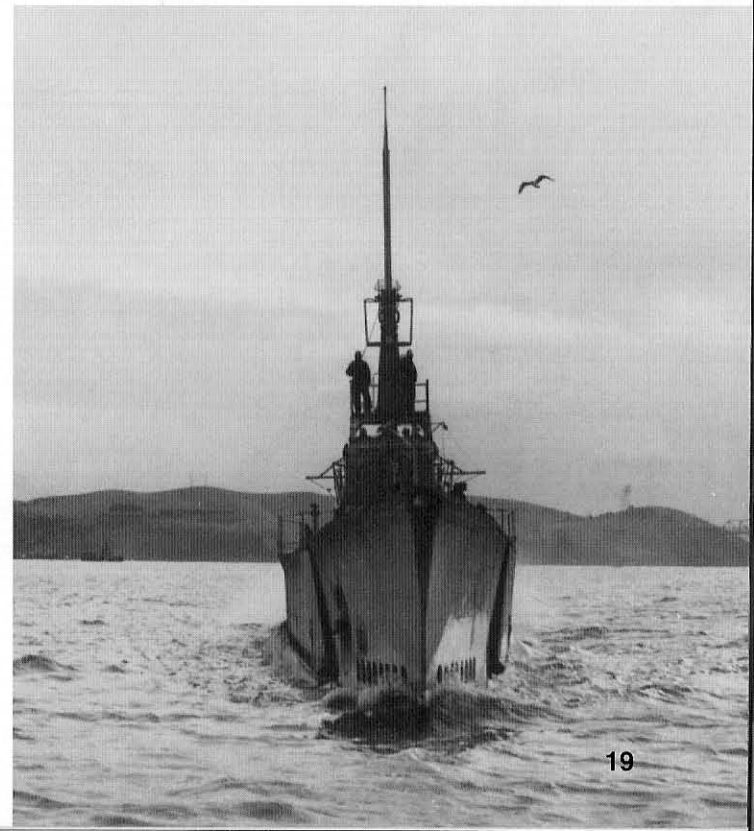


▲ Looking down into *Trigger*'s bridge. The round object is a compass repeater. In the center is the forward TBT (a second one for the aft tubes is visible aft of the SD mast on the opposite page), and partially hidden to the right are the MC speaker and switch box for internal communications. Forward of the bridge is the cigarette deck and the forward deck casing, which both have 20 mm gun mounts. (NARA)

◀ The third of the famous Mare Island trio was *Trigger* (SS 237), which ended the war seventh in total tonnage sunk. *Trigger*'s tower, seen in August 1944, shows typical later wartime features. She has an Oerlikon mount forward and a Bofors mount aft. Like other early boats, her tower plating has been cut away, exposing the farming. Her DF loop has been relocated to a position between the forward periscope and the SJ mast. The vertical stub antenna between her periscopes is for IFF. (NARA)

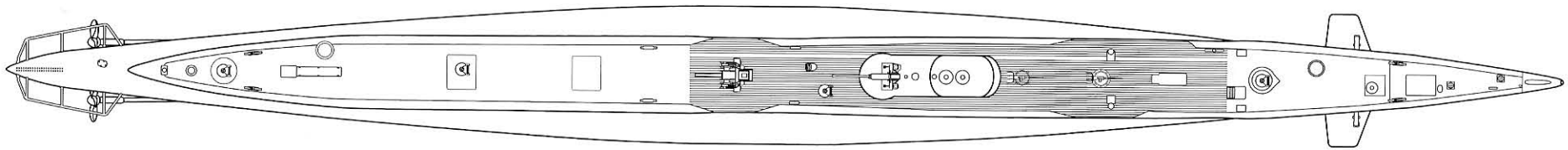


▲ The after deck of *Mingo* (SS 261), seen here on 2 February 1944, shows her plated-over marker buoy well, a feature typical of boats seen later in the war. The aft torpedo hatch is open, and the torpedo loading chute is in position but not erected. Aft of that is the after escape hatch and the stern capstan. (NARA)



▶ *Lapon* (SS 260), seen bow-on on 8 April 1945. Most noticeable are the anchor on the bow's starboard side, the multi-level lookout positions in the periscope shears, and antenna spreaders projecting on either side of the tower. (NARA)

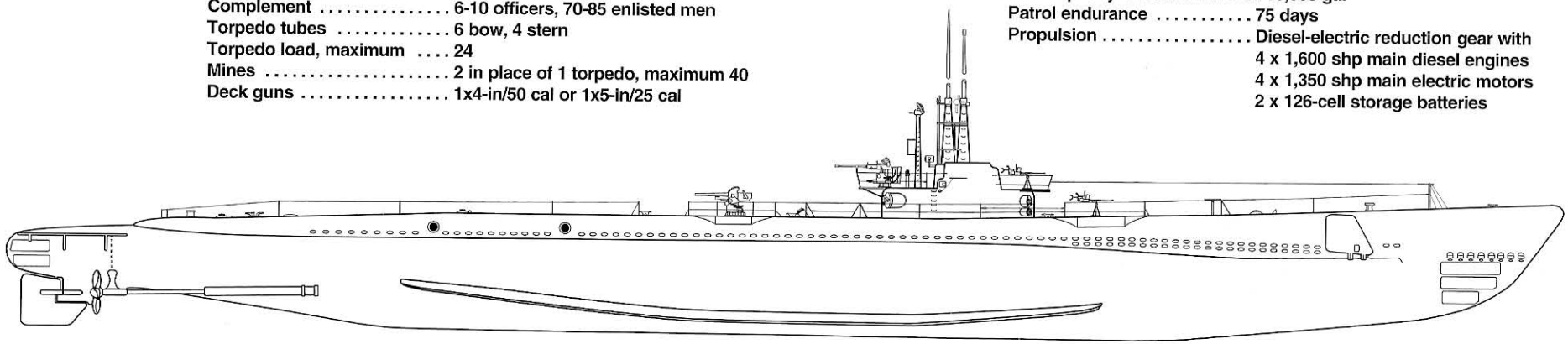
USS *Balao* (SS 285), October 1944

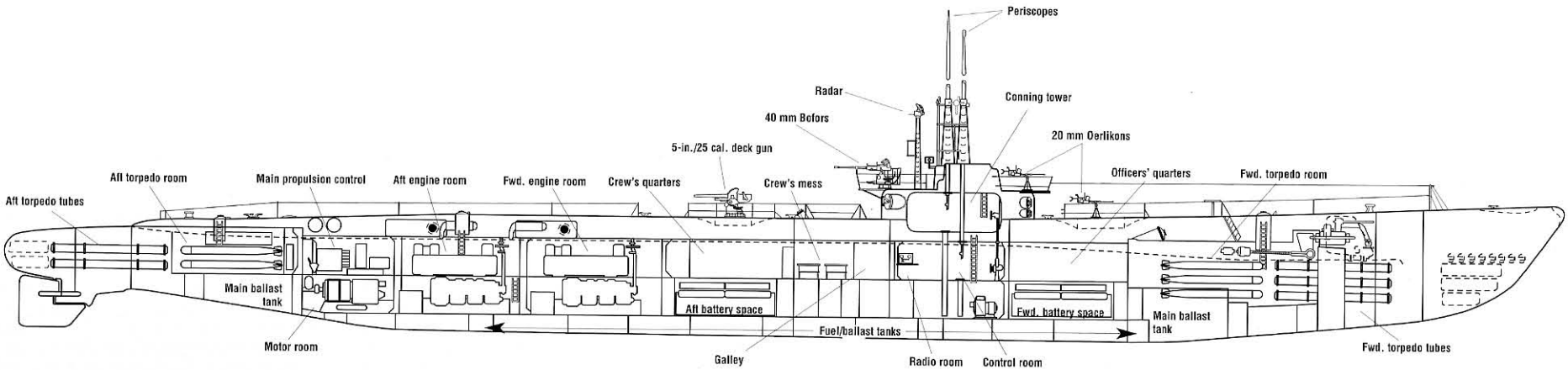


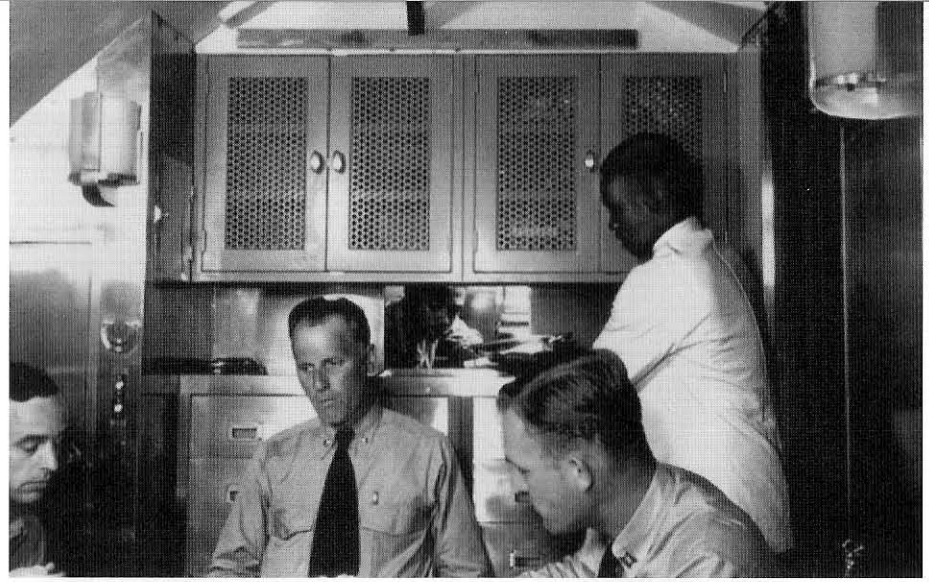
Specifications

Length overall ..... 311 ft 9 in
Beam ..... 27 ft 3 in
Displacement ..... 1,525 tons (normal)
Operating depth ..... 400 ft
Watertight compartments .... 8 plus conning tower
Complement ..... 6-10 officers, 70-85 enlisted men
Torpedo tubes ..... 6 bow, 4 stern
Torpedo load, maximum 24
Mines ..... 2 in place of 1 torpedo, maximum 40
Deck guns ..... 1x4-in/50 cal or 1x5-in/25 cal

Maximum speed ..... 20.25 knots, surfaced
8.75 knots, submerged
Cruising range, surface ..... 11,000 mi @ 10 knots
Submerged endurance ..... 48 hrs @ 2 knots
Fuel capacity ..... 116,000 gal
Patrol endurance ..... 75 days
Propulsion ..... Diesel-electric reduction gear with
4 x 1,600 shp main diesel engines
4 x 1,350 shp main electric motors
2 x 126-cell storage batteries



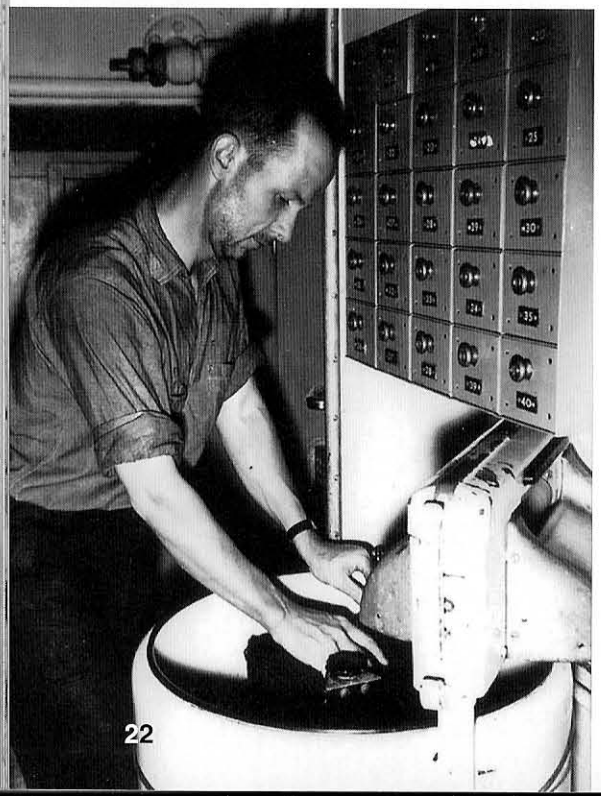




▲ A posed shot looking aft in the wardroom of *Cero* (SS 225). Two mess attendants are serving the boat's Executive Officer, Commanding Officer, and a lieutenant. As would be expected given the times, the officers are all Caucasian and the attendants are African-American or Filipino. The pantry was a serving area only; all food preparation took place in the galley aft of the control room. (NHC)

▶ The captain of *Bullhead* (SS 332), Cmdr. Walter Griffith, looks through the periscope in this posed picture taken in the spring of 1945. A *Gato* was equipped with two periscopes, one with a narrow field and greater magnification for attack and another with a wider field but lower magnification for search. This view looks aft in the conning tower. The TDC is against the bulkhead to the right. (NHC)

▼ Receiving mail was always one of the high points of heading back to port after a mission, and it made for good 'human interest' photos, such as this shot of *Silversides*' (SS 236) wardroom. The 3rd Officer, Lt. Robert Worthington, holds two handfuls of letters. The record of the boat's first four patrols is stenciled on the cabinet doors, and a broom waits for the opportunity to lash it to a periscope. (NHC)



▲ This sailor reclines on his bunk in the narrow space between a torpedo and the overhead in the forward torpedo room of *Bullhead* (SS 332). Another row of bunks is lashed up out of the way so this reload can be moved into a tube after a torpedo is fired. (NHC)

◀ Submariners in the Kriegsmarine and Royal Navy thought U.S. submariners sailed on 'luxury yachts.' This is one of the reasons. No submarine in either of those navies had a washing machine. U.S. submariners also had storage lockers for their valuables, like those on the bulkhead above the washer, unheard of in those other navies. (NHC)

▶ An Electrician's Mate mans the control panel in the maneuvering room on *Batfish* (SS 310), where the electric motors that actually drove the boat were located. On the bulkhead to his left is a repeater for the engine room telegraph, which told him what speed was ordered. (NHC)

Firing a Torpedo

Between the wars, torpedoes were developed which could change course after being fired. This freed the submarine captain from having to point his boat at a theoretical point of impact ahead of a moving target, but introduced enough additional complexity into the firing solution that the rate of successful shots dropped dramatically. Most nations building submarines during this period independently developed a version of a targeting computer, but the U.S. Navy maintained a lead in the development of such a device.

The first Torpedo Data Computer (TDC) was installed in the *Cachalot*-class boats of 1933 and had evolved to a third-generation model by the time the *Gatos* began to be built. The problem for which it was designed was straightforward to describe, just difficult to solve. Two objects (the submarine and the target) are moving on two different headings at two different speeds. Aiming a torpedo is simply a matter of determining (1) how long it would take a torpedo to cover the distance between the two objects and (2) aiming at where the target would be at the end of that time. This is little different from shooting skeet, where a target moving at an angle to the shooter must be led properly to get a hit, except that in this case the shooter (1) is moving, (2) must shoot in the direction he happens to be pointing, and then (3) aim his shot by having it change direction a fixed length of time after it was fired. Prior to the TDC, firing solutions often took a long time to obtain and needed to be constantly updated as the submarine approached a target that might well be changing course or speed. If more than one torpedo was fired, it was standard practice to give each one a slightly different course adjustment, so that by the time they reached the target they would be 'spread' between one-quarter and one-half a ship-length apart, based on the target's estimated size and speed.

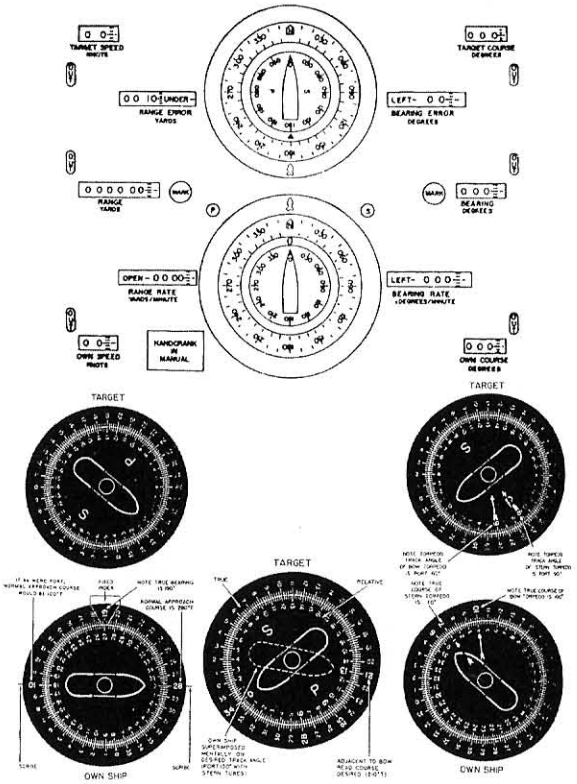
The Mk III TDC with which *Gatos* were fitted was divided vertically into two halves, each with a different function and its own set of input wheels and read-out dials. The left half was known as the 'Position Keeper,' and was used for the entry and display of data related to the range, speed, course, and bearing of the submarine and the target. As the war progressed, much of this data entry was automated, with the submarine's data coming from the pitometer log and compass, and target bearing coming from radar or sonar. It became an increasingly common practice later in the war to fire torpedoes at targets that were never identified or sometimes even sighted visually.

The right half of the Mk III TDC was the 'Angle Solver.' It produced the actual firing solution, specifically the gyro angle correction for each torpedo in a spread. This calculator continuously updated the solution as revised data was fed into the Position Keeper. The TDC operator had to manually identify the torpedo tubes to be fired and the characteristics of the torpedo in each tube, but beyond that, the TDC continually and automatically fed updated gyro angle settings into each designated torpedo tube. These two features — the continual updating of the gyro angle and the automatic setting of each torpedo's gyroscope — made the TDC different from and markedly superior to either of its British or German counterparts.

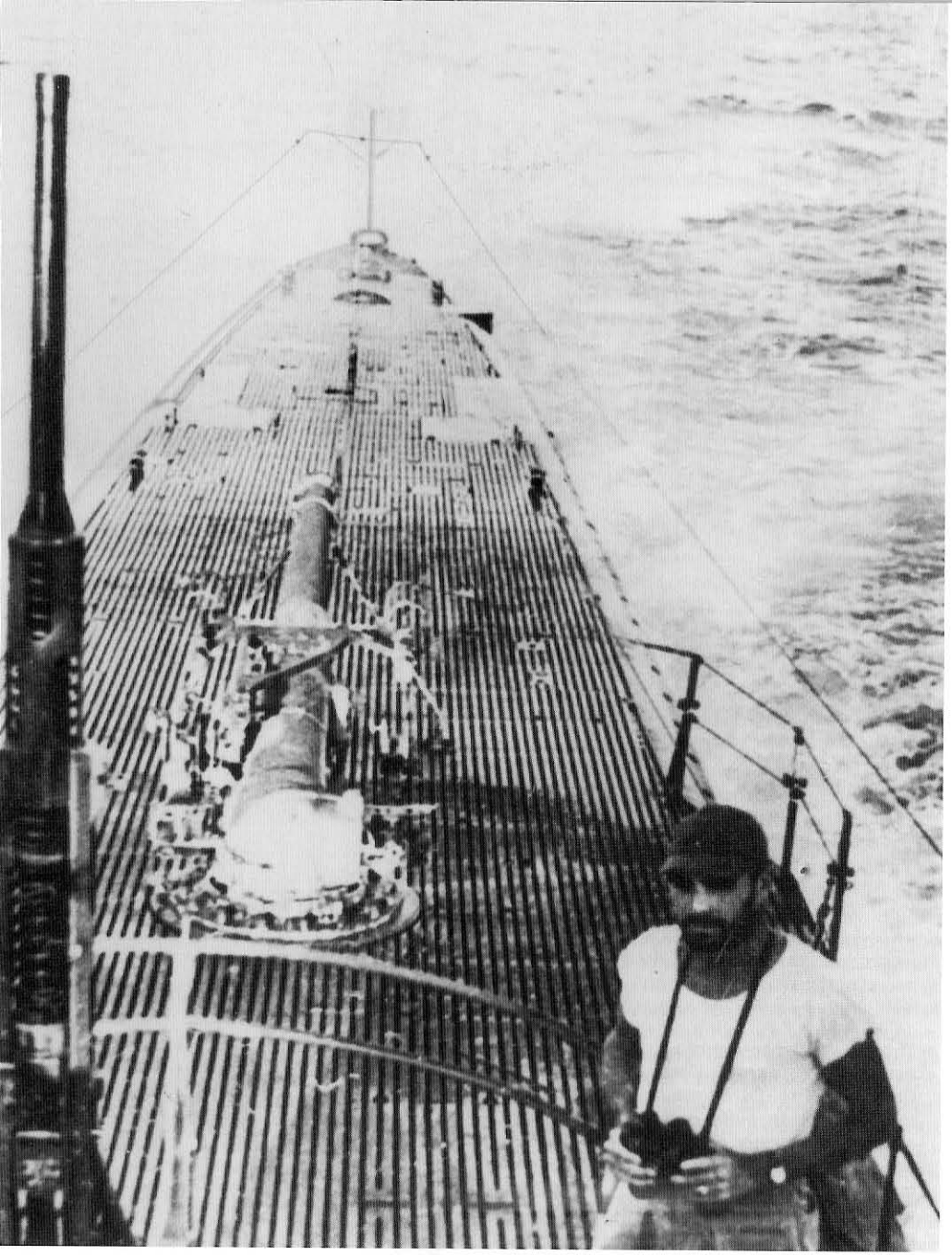
Of course, the best firing solution in the world meant nothing if the torpedo failed to operate properly. Of the major combatants in World War II, only the Japanese seem to have fought the war with well-tested submarine torpedoes that worked as designed from the beginning. The Americans, with the possible exception of the Germans, probably had the most trouble ironing out the various glitches that prevented the standard Mk 14 torpedo from operating as designed. Like the Germans, the Americans had designed a magnetic influence exploder in great secrecy between the wars and had deployed it with minimal testing for fear that the secret might be revealed. The result was a fuse that worked as designed less than half of the time. Add to this an unreliable contact exploder, the Mk 14's tendency to run deep, and a rare, but very frightening, penchant for it to run a circular course, and American submariners sometimes wondered whether the Japanese or the Navy's own Bureau of Ordnance was the more dangerous enemy.

(▸▸ 24)

▲ **Crewmen on an unidentified boat load a torpedo aft using the chute that held the 'fish' at the proper angle to enable it to slide through the loading hatch. The marker buoy well in the after deck has been plated over. (NARA)**



▸ **The dials and displays of an early Mk III Target Data Computer. The TDC allowed the operator to enter data such as the range, course, speed, and bearing of the target and similar data for his own boat. As the war progressed and electronics improved, much of this data was eventually entered automatically from the radar, gyrocompass, and pitometer log. (NHC)**



▲ Jim Blanchard poses on the aft cigarette deck of *Albacore* (SS 218), probably in early 1944. To the left is the barrel of the aft 20 mm Oerlikon, showing its recoil spring. Further aft was the 4-inch, 50-caliber deck gun, which was popular for its ease of use but had a muzzle velocity too high for the kinds of light targets *Gato*'s most often shot at. (SFL)

Guns

The primary offensive weapon of a *Gato*-class submarine was the torpedo, but boats of that era carried a variety of guns for a variety of purposes. The guns fell into two main categories: deck guns, primarily to be used for sinking targets too small to warrant expending a torpedo, and anti-aircraft guns, primarily for, as the name implies, defending against aircraft.

Deck Guns

Gatos had 'hard-points' built into the deck casing so that a gun could be mounted either forward or aft of the tower. In a small number of cases, 5-inch guns were carried both forward and aft late in the war.

3-inch (76.2 mm), 50-caliber. This was the standard submarine deck gun up through the start of World War II. It came in a variety of models and marks, differing mainly in the rifling. It was considered an easy gun to man and fire, but fired too light a shell (13 pounds — 5.9 kg) to be very effective against small ships. Experience led to the demand for heavier deck guns with more punch.

4-inch (102 mm), 50-caliber. Originally mounted on some S-class submarines, these guns were recycled for use on *Gatos* as a stop-gap replacement for the lightweight 3-inch gun. This gun fired a 33-pound (14.97 kg) projectile. Its main disadvantage was a high muzzle velocity (2,900 feet per second — 884 m/s) which often caused the round to pass right through lightly built targets.

5-inch (127 mm), 25-caliber. This weapon was unique in not requiring a muzzle plug (tampion), because the Mk 17 version designed for submarines had a corrosion-resistant barrel lining, which made the gun very fast to set up and fire. It fired a 53.85-pound (24.43 kg) high explosive (HE) shell with a 5.63-pound (2.55 kg) bursting charge at 2,200 feet per second (808 m/s). It was considered ideal for its intended purpose.

Anti-Aircraft Guns

Generally, these were carried in the tower structure, but late in the war, some *Gatos* carried an Oerlikon mount on the unoccupied deck hard-point.

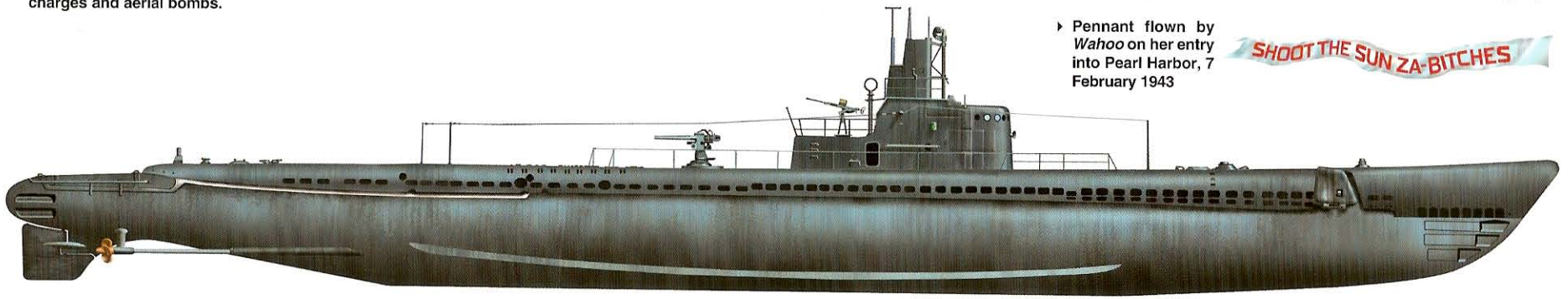
.30-caliber (7.62 mm) Browning Machine Gun. The ubiquitous Browning .30-caliber machine gun was the initial anti-aircraft gun mounted on the earliest *Gatos*. The first mountings were water-cooled, later replaced by the simpler air-cooled version. *Gatos* generally had several pintle mounts for .30-caliber machine guns along the edges of the deck casing, where guns could be mounted mainly for the 'control' of survivors found floating in the water. Some early *Gatos* carried .50-caliber (12.7 mm) machine guns in the place of the .30-caliber. The larger .50-caliber wasn't popular because it was only slightly more effective as an anti-aircraft gun and was a great deal heavier and more awkward to pass up or down the tower hatch in a hurry.

20 mm, 70-caliber Oerlikon. Intended as a replacement for the .30-caliber Browning, the Oerlikon was a Swiss design built under license in the United States. When the earliest *Gatos* were modified by the addition of 'cigarette decks' forward and aft of the tower, a single Oerlikon mount on each deck was the standard fit. Later in the war, twin mounts replaced some single mounts.

40 mm, 60-caliber Bofors. This was a Swedish design adopted by the Navy when it became obvious that the indigenous 1.1-inch (28 mm), 75-caliber was unreliable and too light to be effective against 1940s-era aircraft. License production actually began before that of the Oerlikon. Single Bofors mounts were experimentally fitted to *Gato*-class submarines in early 1944. These were so successful, that these mounts became standard before the end of the year, limited only by availability.

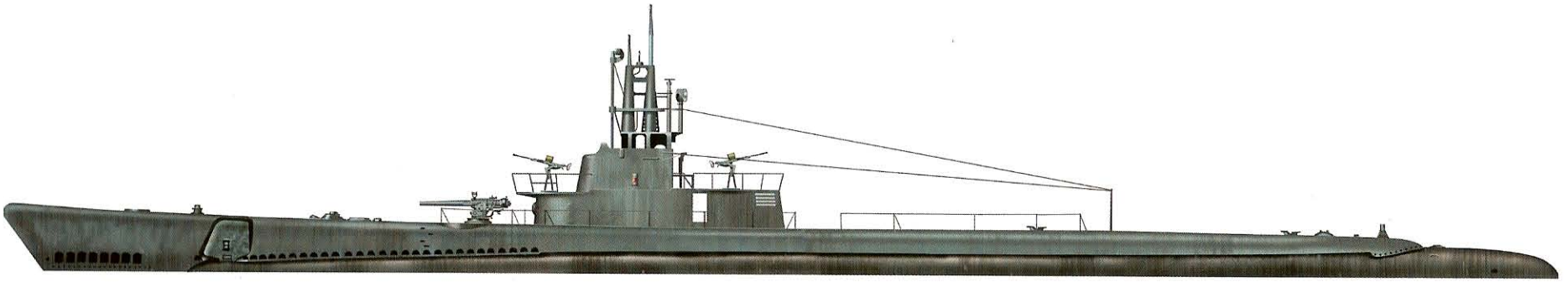
(▸▸ 32)

- USS *Wahoo* (SS 238), August 1942 in Measure 9 (overall black). Her tower has been cut down aft, and periscope shears are plated in. She carries a three-inch gun aft and a 20 mm mount on the aft cigarette deck. *Wahoo* earned six battle stars for her World War II service, during which she sank twenty-seven ships totaling 119,100 tons, and damaged two more totaling 24,900 tons. She failed to return from her seventh patrol in September-October 1943. In July 2006 a team of Russian divers located a sunken submarine 213 feet (65 m) below the surface in the Soya (LaPerouse) Strait between Hokkaido, Japan and Sakhalin, Russia. On 31 October 2006, Commander, U.S. Pacific Fleet, confirmed that the submarine is indeed USS *Wahoo,* believed to have been sunk by a lengthy Japanese combined sea and air attack involving depth charges and aerial bombs.

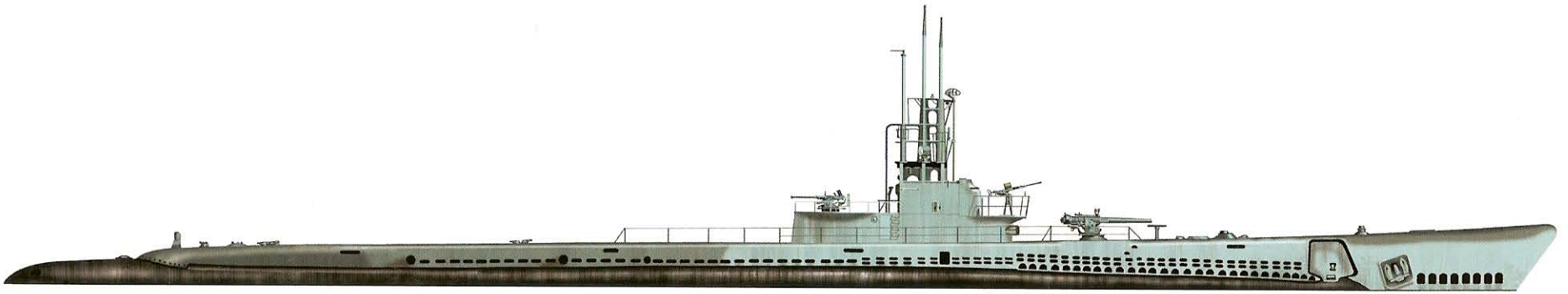


- Pennant flown by *Wahoo* on her entry into Pearl Harbor, 7 February 1943

- USS *Drum* (SS 228), 1944, in Measure 9. She is fitted with an SJ mast forward of open shears and an SD mast aft, 20 mm mounts on the fore and aft cigarette decks, and a four-inch deck gun forward. *Drum* received a total of twelve battle stars for World War II service. She is credited with sinking fifteen enemy ships totaling 80,580 tons, the eighth-highest total of Japanese tonnage sunk by all U.S. submarines. USS *Drum* is preserved as a memorial at Mobile, Alabama, where she is moored alongside the battleship USS *Alabama* (BB 60).



- USS *Trigger* (SS 237), 1945, In Measure 32/3SS-B, popularly known as the 'light gray job.' The conning tower sides and hull from the bow to just aft of conning tower were painted Haze Gray 5-H, blending into Ocean Gray 5-O, which in turn blended into a dull black stern. Decks were painted Gloss Black out to a distance of two feet from the deck edge. Her original Measure 9 dull black showed through in patches where the Haze Gray and Ocean Gray were chipping. Deck guns were painted dull black on the upper half and Very Light Gray on the lower half. Saddle tanks were matt black, extending to the aft end of the boat. *Trigger* received eleven battle stars for World War II service and three Presidential Unit Citations and is credited with sinking eighteen ships totaling 86,552 tons. When she failed to arrive at Midway from her twelfth patrol by 1 May 1945, she was reported as presumed lost in enemy waters. *Trigger* is believed to have been sunk in the East China Sea by Japanese forces on 28 March 1945.

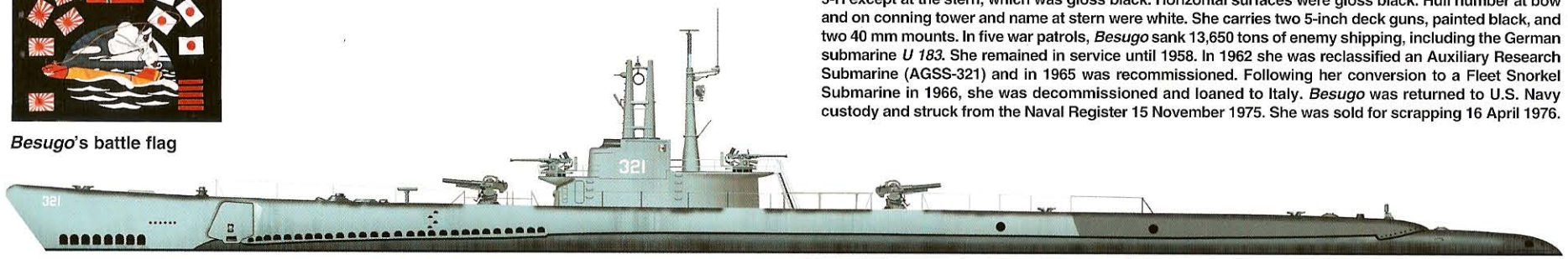


▾ *USS Bowfin* (SS 287), November 1944. She carries a 4-inch deck gun forward and one 40 mm and one 20 mm mount, and is equipped with both SD and SJ radars on a low conning tower with simplified shears. She is painted in a simplified Measure 32/9SS (the 'dark gray job'), a scheme similar to Measure 32/3SS-B, except that Ocean Gray 5-O was used instead of Haze Gray 5-H. Vertical sides of the hull were Ocean Gray 5-O, blending into dull black aft. The conning tower and shears were Navy Gray (medium gray), with white countershading under the cigarette deck overhang. Horizontal surfaces and saddle tanks were as for Measure 32/3SS-B.

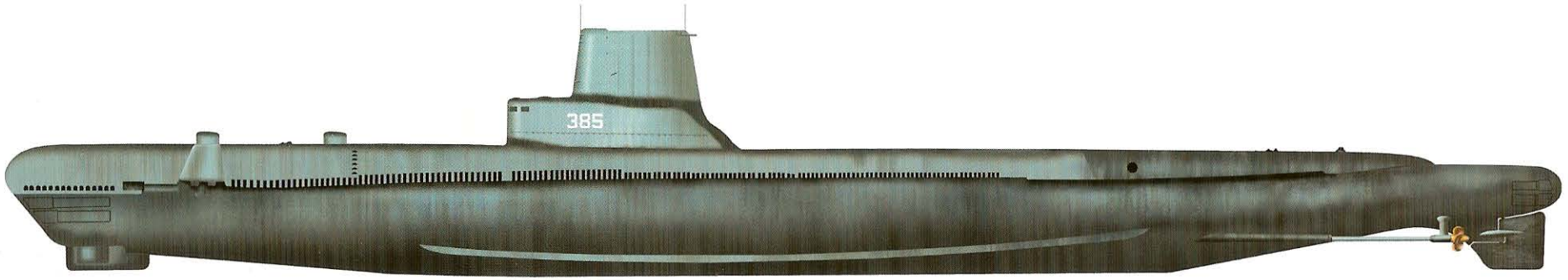
Launched on the first anniversary of the attack on Pearl Harbor, *Bowfin* completed nine war patrols in two years of wartime duty and is credited with sinking sixteen Japanese vessels totaling 67,882 tons. Today she is preserved as a memorial at Pearl Harbor, Hawaii. *Bowfin* was added to the National Register of Historic Places in 1982 and designated a National Historic Landmark in 1986.

Besugo's battle flag

▾ USS *Besugo* (SS 321), late 1940s, in a variant of Measure 32/3SS-B. All vertical surfaces were Haze Gray 5-H except at the stern, which was gloss black. Horizontal surfaces were gloss black. Hull number at bow and on conning tower and name at stern were white. She carries two 5-inch deck guns, painted black, and two 40 mm mounts. In five war patrols, *Besugo* sank 13,650 tons of enemy shipping, including the German submarine *U 183*. She remained in service until 1958. In 1962 she was reclassified an Auxiliary Research Submarine (AGSS-321) and in 1965 was recommissioned. Following her conversion to a Fleet Snorkel Submarine in 1966, she was decommissioned and loaned to Italy. *Besugo* was returned to U.S. Navy custody and struck from the Naval Register 15 November 1975. She was sold for scrapping 16 April 1976.

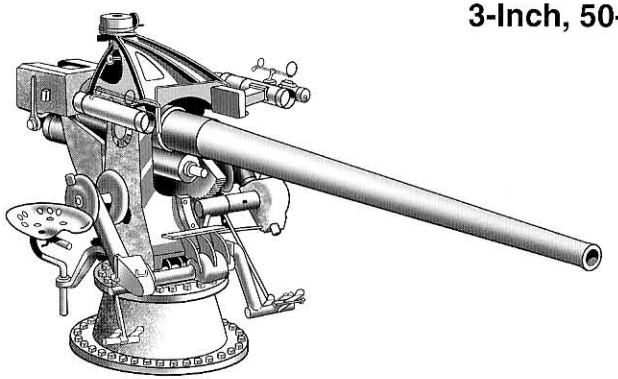


▾ USS *Bang* (SS 385) in GUPPY IIA configuration, June 1958. She is painted in Measure SS 17 G, one of three post-war color schemes developed for the 'Guppy' submarines. Vertical surfaces were painted Ocean Gray 5-O from the pressure hull to the topmost part of the boat. Vertical surfaces inside the bridge structure, periscope necks, and streamlined periscope fairings were painted Haze Gray 5-H. 'Deck paint' (a glossy, dark-gray, near-black color) was applied to all decks, except on rounded edges. Dull black was used on all rounded surfaces, including the pressure hull and deck edges, and was blended into the Ocean Gray. *Bang* completed six war patrols during World War II and is officially credited with sinking eight Japanese merchant ships totaling 20,177 tons while operating in the South China and Philippine Seas. Post-war, she was converted to a GUPPY-type submarine and recommissioned in 1952. Thereafter, *Bang* continued operations and training work as part of the Atlantic Fleet, making occasional deployments to the Mediterranean Sea and northern European waters through the rest of the 1950s and during the 1960s. Decommissioned in 1972, she was sold to the Spanish Navy in 1974 and renamed *Cosme Garcia* (S-34). In 1983 she was sold by the Spanish Navy to be scrapped.

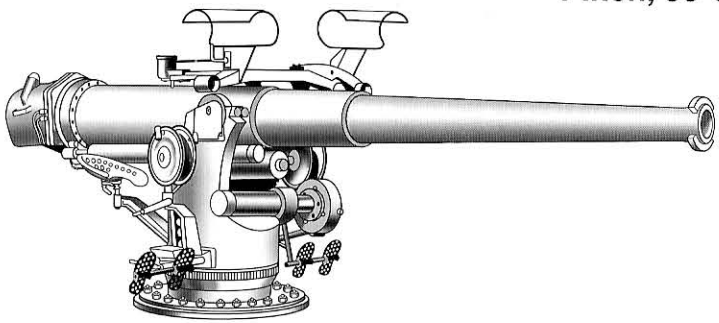


Deck Guns

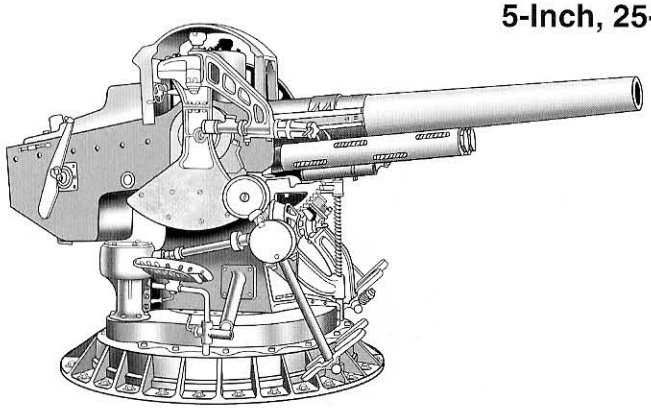
3-Inch, 50-Caliber



4-Inch, 50-Caliber

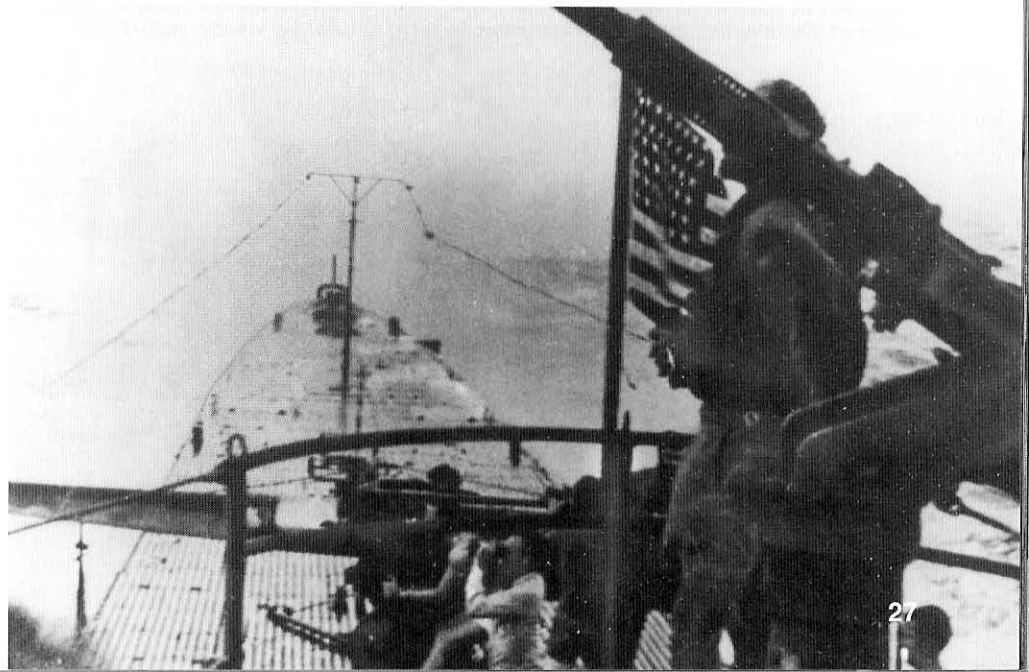


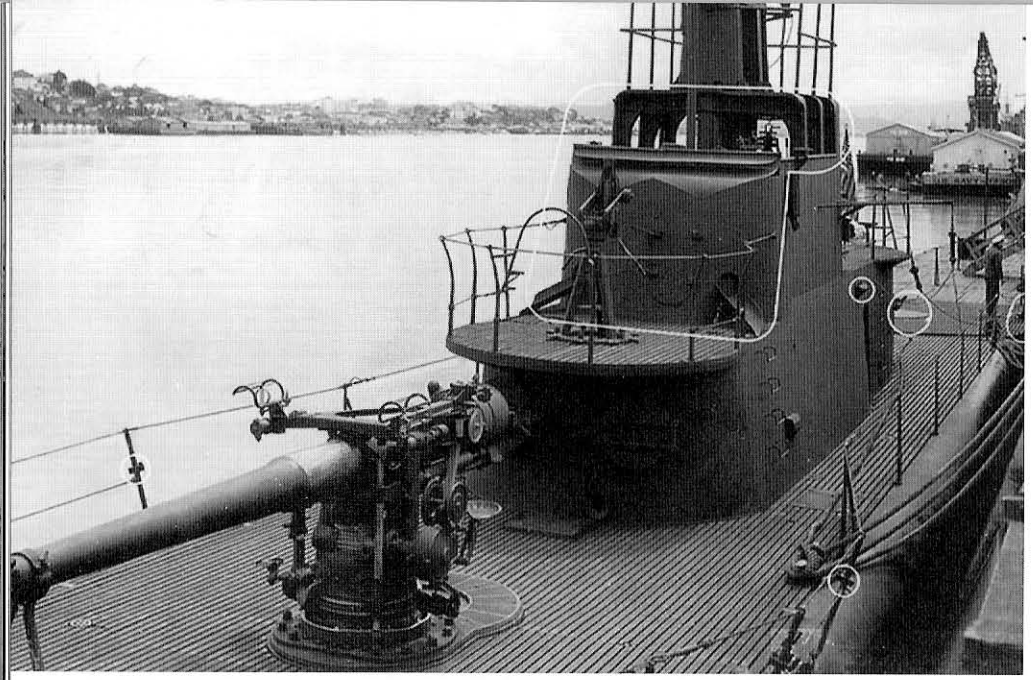
5-Inch, 25-Caliber



▲ Shelling a sampan was a relatively safe activity, so this crew of the 3-inch, 50-caliber deck gun on *Silversides* (SS 236) could afford to look relaxed and take their time. Submarines rarely shot their deck guns at anything that could shoot back. That was what torpedoes were for. (NARA)

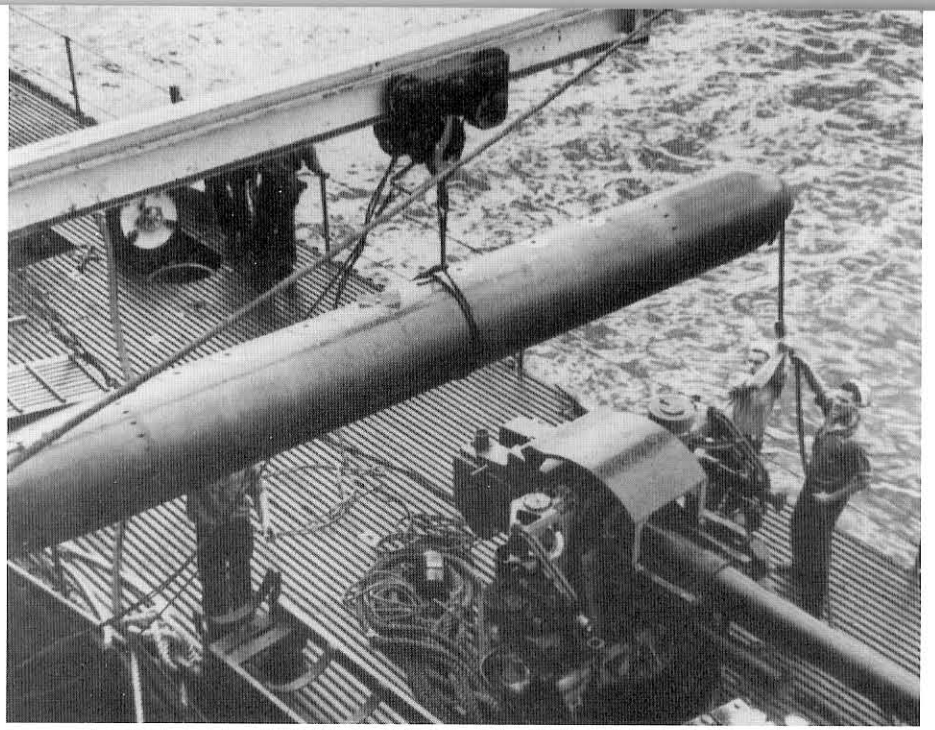
▼ The gun crew on *Albacore* (SS 218) fires the 4-inch, 50-caliber at a soft target, most likely a sampan or a trawler. They look a bit more warlike than the crew on *Silversides*, but not much. (NHC)





▲ A forward 4-inch, 50-caliber gun on *Flier* (SS 250), seen at Mare Island, 27 April 1944. The hard point on the deck casing could accept guns of many different base diameters. The gun was painted dull black like the rest of the boat, except where the barrel slid through the mount; this area was unpainted, greased steel. (NHC)

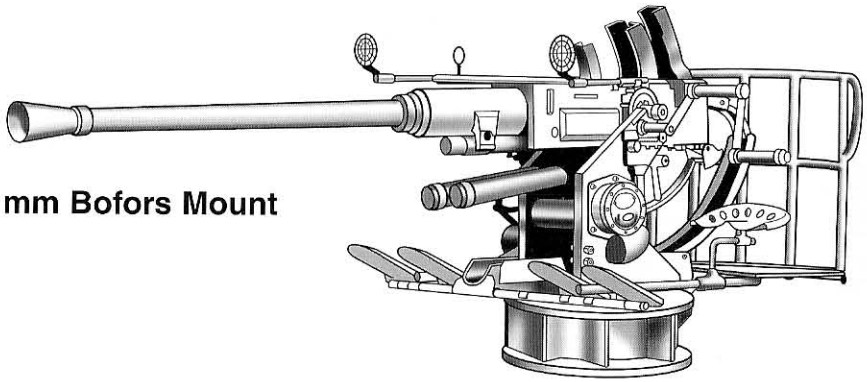
▼ Vice Admiral Charles Lockwood – COMSUBPAC – celebrates the end of a successful cruise by *Balao* (SS 285) in early 1945. Lockwood is to the left, behind the barrel of *Balao*'s 5-inch, 25-caliber gun, painted with a Japanese merchant flag and six hashes, indicating the number of small ships sunk by this gun. Next to him facing the camera is *Balao*'s captain, Robert Worthington, the same officer seen earlier in *Silversides*' wardroom. (NARA)



▲ A torpedo is loaded over the 5-inch, 25-caliber deck gun of an unidentified submarine, May 1945. A trolley next to the gun waits to receive the torpedo. (NARA)

▼ The 5-inch, 25-caliber gun was originally designed as an anti-aircraft weapon and could be elevated to extremely high angles, as seen in this view of the gun on the afterdeck of *Sea Cat* (SS 399). (NARA)

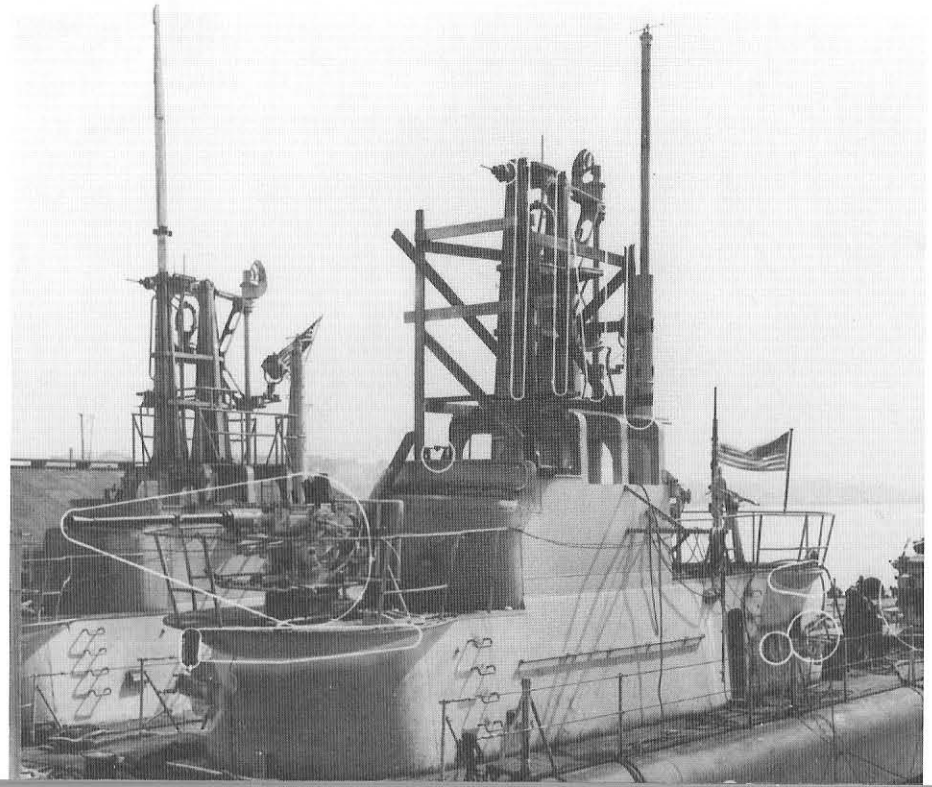
Anti-Aircraft Weapons



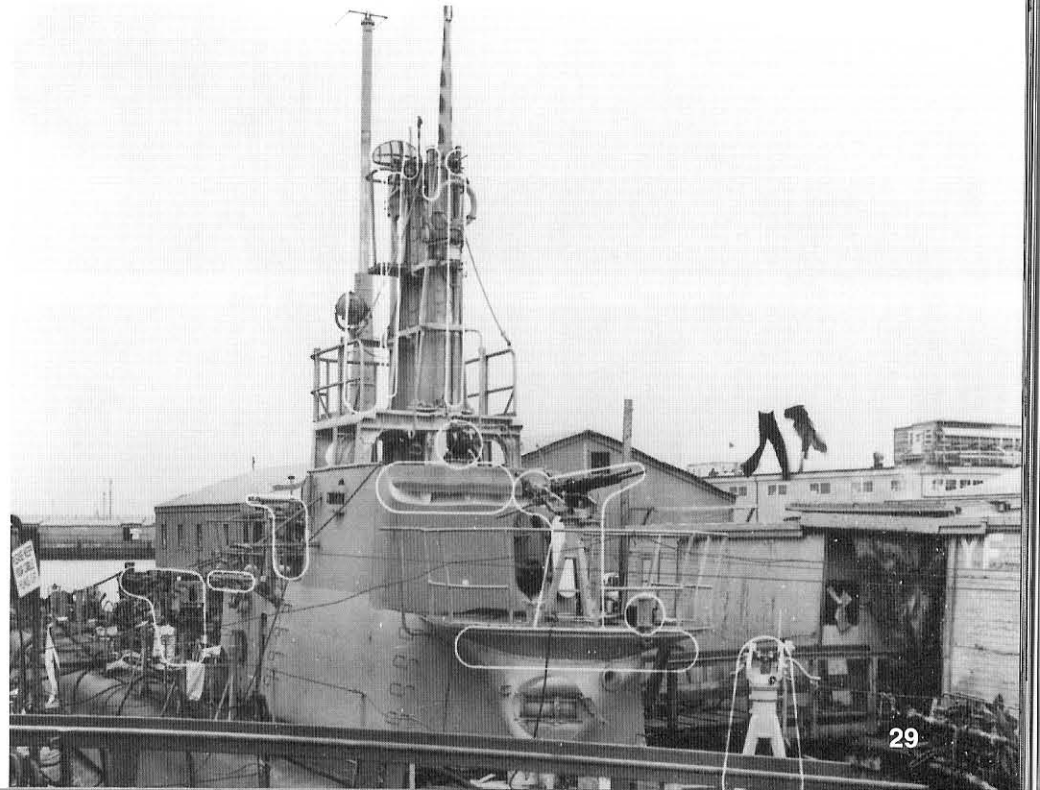
40 mm Bofors Mount

▲ All three of the standard light weapons carried on a late-war *Gato* can be seen in this photograph of an unidentified boat, possibly *Balao* (SS 285), as she returned to Guam from patrol in early 1945. A pair of air-cooled Browning .30-caliber machine guns are on pintle mounts along the deck edge, the barrel of a 20 mm Oerlikon rises from the afterdeck hard point behind the waving crewmen and a 40 mm Bofors mount is on the after cigarette deck. The crew is obviously happy, having just received mail from home. (NARA)

▼ *Ray* (SS 271) seen here at Mare Island, 12 March 1945, has a 40 mm Bofors mount on her forward cigarette deck. She is also painted in Ms 32/9SS. The submarine alongside *Ray* in the background is unidentified. Although both boats are *Gato*s, they display many differences in details. (NARA)



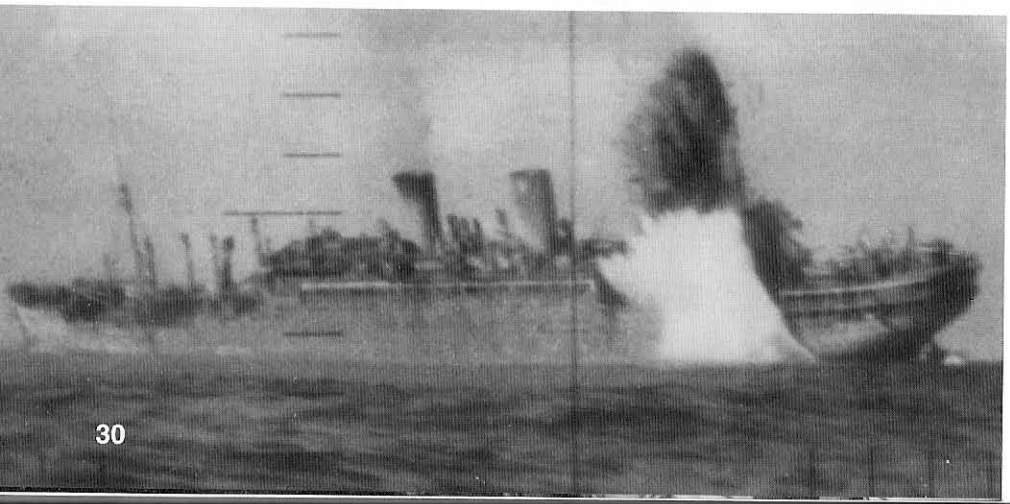
▼ This view of *Lapon* (SS 260) at Mare Island on 20 April 1945, shows a rarely seen weapon on her forward cigarette deck, a twin 20 mm Oerlikon mount. *Lapon* is painted in Measure 32/9SS, which required vertical surfaces, such as the sides of the tower, to be painted Ocean Gray 5-O with white counter-shading under overhangs, as shown here. (NARA)

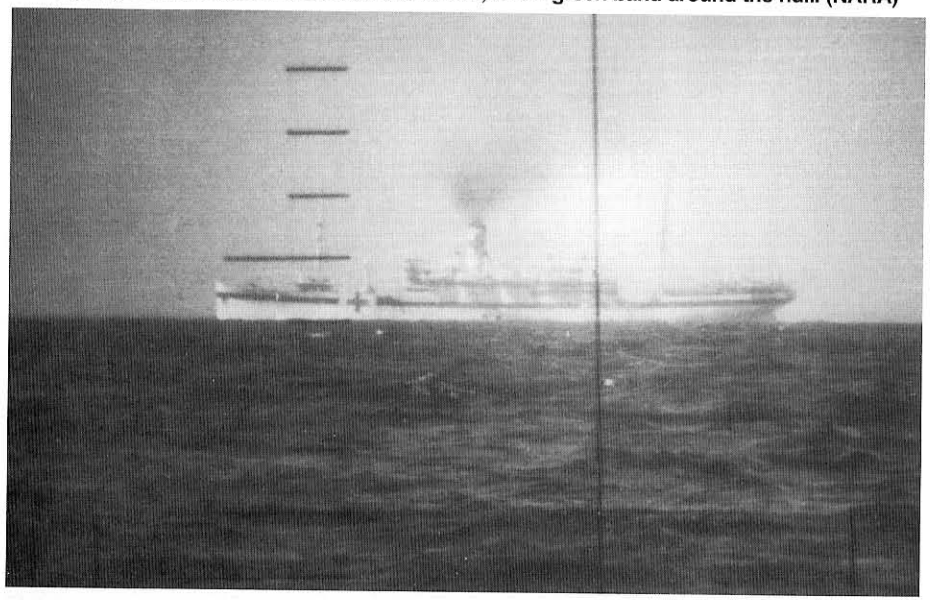


◂ *Darter* (SS 227) became grounded on Bombay Shoal near Palawan in the Philippines on 24 October 1944. Unable to work herself loose, she was abandoned and her crew taken off by *Dace*. Demolition charges were set, but did little damage. *Dace* fired four torpedoes, which exploded on the shoal short of *Darter,* and then pumped thirty rounds from her deck gun into the target, making sure she'd not float again. Nevertheless, she was inspected by the Japanese the next day. At least two other submarines tried to destroy the wreck later in the month, but she remained intact well into the 1950s, and parts of her hull can still be seen at low water. (NHC)

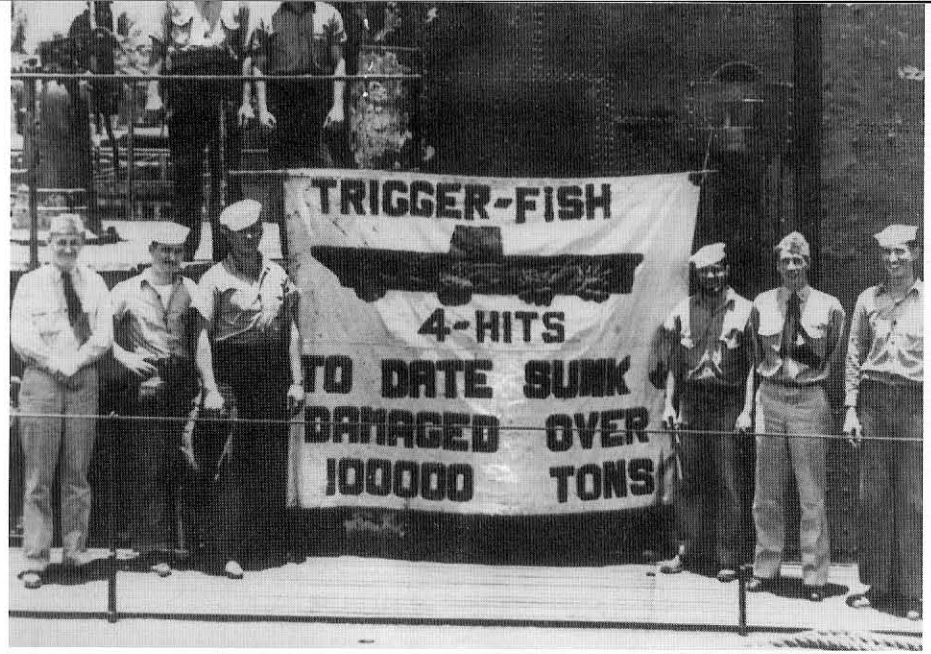
◂ The old destroyer *Okikaze* was sunk by *Trigger* (SS 237) off Yokusuka on 10 January 1943. *Trigger* fired three torpedoes; one hit *Okikaze* at the break of her forecastle, which folded up at a 45-degree angle, and a second hit near her stern. *Okikaze* sank on an even keel, as seen here. Periscope photographs such as this were not common, depending on the availability of a camera to the captain and time to snap the picture. (NARA)

▾ And then there are the ones that must be left alone. In one of many incidents on a highly eventful patrol, *Silversides* (SS 236) sighted and let pass the Japanese hospital ship *Asami Maru* on 4 January 1943. She was painted according to International Red Cross rules: a white hull, large red crosses on hull side and funnel, and a green band around the hull. (NARA)



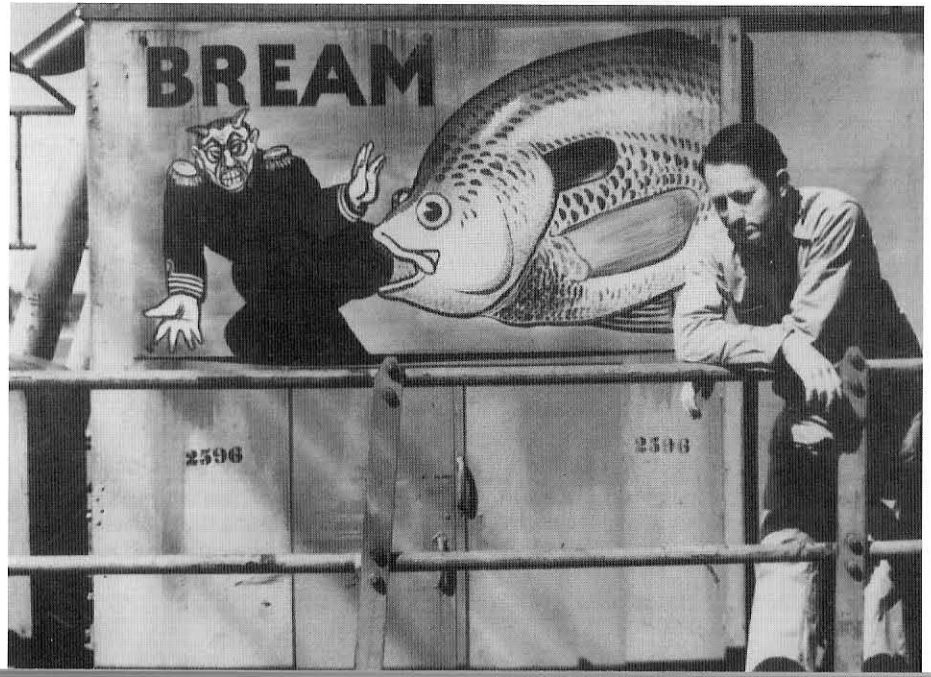


◂ *Puffer* (SS 268) sank this large transport, *Teiko Maru* (formerly the French liner *D'Artagnan* of over 15,000 tons) on 22 February 1944. Even more rare than periscope photographs are those that show a torpedo actually exploding against a target. (via Bob Cressman)



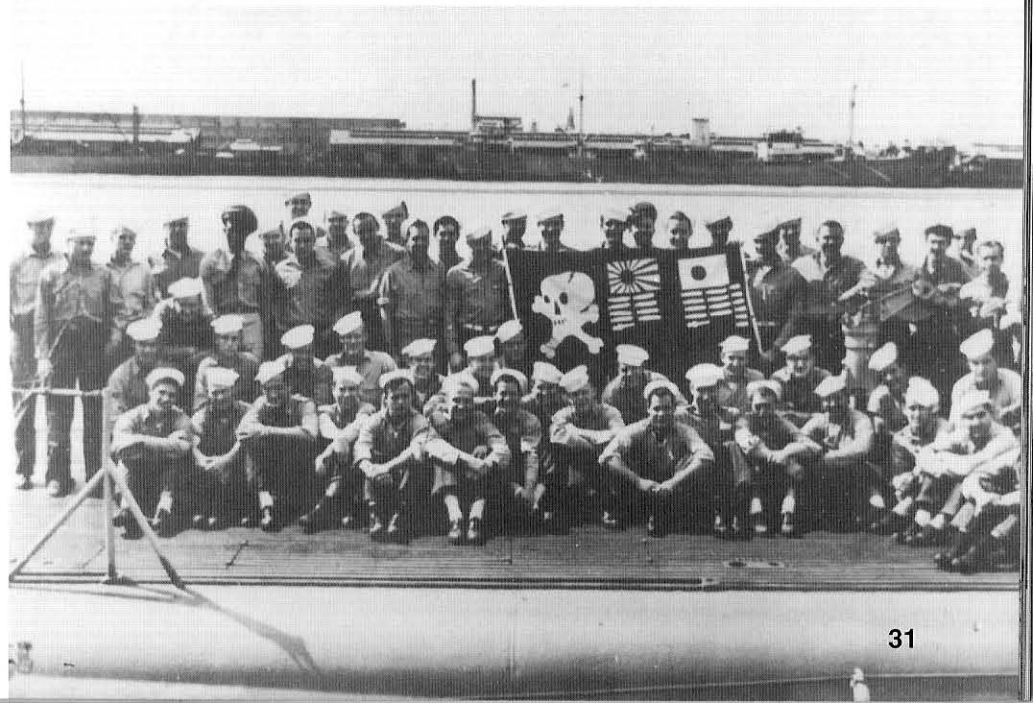
▲ American submarines, following a Royal Navy tradition dating back to the World War I, created 'pirate flags' recording their claimed victories. Crewmen on *Trigger* (SS 237) display this flag, including an image of an aircraft carrier (which looks distressingly like USS *Saratoga*) being hit four times. In fact *Trigger* put two torpedoes into the Japanese carrier *Hiyo* on 10 June 1943, knocking her out of the war for five months. (NARA)

▼ While *Bream* (SS 243) was being readied for launch at the Electric Boat yard, she displayed not a flag, but a placard. Wartime propaganda often played up the racial element of the Pacific War. (NARA)



▲ A small flag, in the more traditional black, shows a pelican in a sailor's cap emerging from a hatch with *Greenling*'s hull number (SS 213) and has eleven flags indicating victories and the legend "SO SOLLY." (Maynard Knutson)

▼ The most traditional of the victory flags was from *Growler* (SS 215), complete with the skull and crossbones. (SFL)



▲ **The name-boat of the second subclass of *Gatos*, *Balao* (SS 285) is seen at Mare Island on 25 October 1944 near the end of a major refit. A distinctive feature of most of the boats of the subclass was the bulge on the starboard face of bridge, here accentuated by the camouflage scheme, which seems to be a combination of the lighter Measure 32/3SS-B, as evidenced by the light gray tower, and the darker Measure 32/9SS, evidenced by the medium gray hull. The main distinguishing feature of all *Balaos* was the simplified and more substantial periscope shears and the lower tower without the exposed framing. In this view, *Balao* has the separate radar mast located on her after cigarette deck. This was added during this refit; it was not an original feature of early *Balaos*. (NARA)**

The *Balao* Sub-class

No sooner had the smoke cleared at Pearl Harbor than a flood of orders for more ships came from the Navy. On 1 January 1942, orders went out for twenty-three more submarines (SS 285-307) for the FY 1942 war budget. Seven of these were ordered from Portsmouth Naval Yard, four from Mare Island, and twelve from Cramp Shipbuilding in Philadelphia. In April this number was increased to thirty, the expected annual wartime attrition. Five of these orders went to Portsmouth, which was bringing a fifth building slip on line, and two to Electric Boat, which was also rapidly expanding capacity. Over the next year, 102 additional hulls (SS 315-416) were ordered: forty-six from Electric Boat, twenty from Manitowoc, thirty from Portsmouth, and six from Mare Island. Mare Island Naval Shipyard, in the northern reaches of San Francisco Bay, produced fewer boats than the other yards mainly because it was the primary refit yard for Pacific theatre submarines, and very few slips were free for new construction. The Cramp yard, which had gone bankrupt during the Depression and was resurrected to support the war effort, had trouble meeting schedules and quality requirements, and three of the boats ordered from Cramp were completed after launch at Portsmouth and Boston naval yards.

These 132 new boats formed a distinct sub-class, named for the lead boat, USS *Balao* (SS 285). Few of the changes made in this sub-class were visible. Most had to do with simplifying some internal arrangements to speed up production. The most important change was the adoption of thicker and stronger steel — ⅞-inch (22.2 mm), 35-pound (15.9 kg) high-tensile steel (HTS) — for the pressure hull. Some submariners feared the HTS might prove more fragile under depth charging than the mild steel used in the *Gatos*, but experience showed no such effect. The immediate benefit was an increase in test depth to 400 feet (121.9 m) and calculated crush depth to 600 feet (182.9 m). The designers believed that these limits could be increased even further; however, the limiting factors were not the strength of the hull, but the integrity of the seals where the hull was penetrated, such as propeller shaft glands, and the ability of the trim pumps to operate at higher water pressures. Electric Boat had a harder time than government yards switching over to the thicker hull due to a large backlog of orders for the original *Gato* boats and a greater investment in tooling for the thinner hull. Nevertheless, they were able to switch over in time to begin their FY '42 construction with *Perch* (SS 313). Manitowoc, which depended on Electric Boat for drawings, completed its first four *Balaos* (SS 361-364) with the thinner hull before they were able to make the switch. These four were the only *Balaos* not to have the thicker hull. Toward the middle of *Balao* production, the design of the after torpedo room was modified to allow an additional four reloads to be carried, bringing the total torpedo capacity to twenty-eight. This change was retrofitted to many earlier boats.

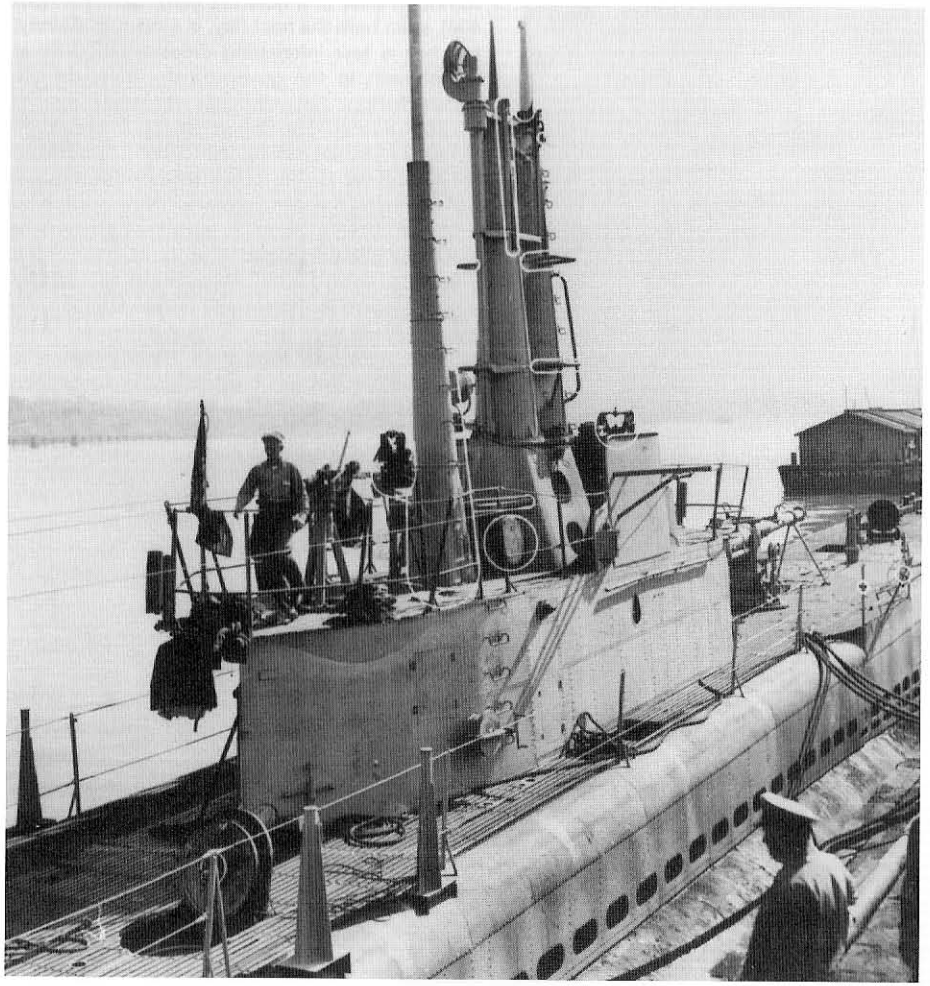
The *Balaos* were built with external features causing them to resemble earlier *Gatos* emerging from mid-war refits. Forward and aft of the open bridge, they had large cigarette decks on which were sited single 20 mm Oerlikon mounts. The gun itself, barrel and breech, was stored below when the boat submerged. The bridge was lower than of the *Gatos* and eliminated much of the framing around the periscope shears. They all had a venturi wind deflector of varying design built into the bridge's forward edge. A typical *Balao* had antennas for SD air search and SJ surface search radars when completed. Later-production *Balaos* were completed with a free-standing radar mast that was added to other boats during refit. The standard deck gun was a 4 inch, 50-caliber mount.

The first *Balao* to be commissioned, on 4 February 1943, was the name boat. Of the 132 *Balaos* ordered, 122 were completed, and ten were cancelled in 1944 when it became obvious that the boats already building would be more than adequate. Eight of the cancelled ten were from Electric Boat's massive order; the other two were Manitowoc boats. Of the completed boats, 101 were ready in time to conduct at least one war patrol. Of those, ten were lost.

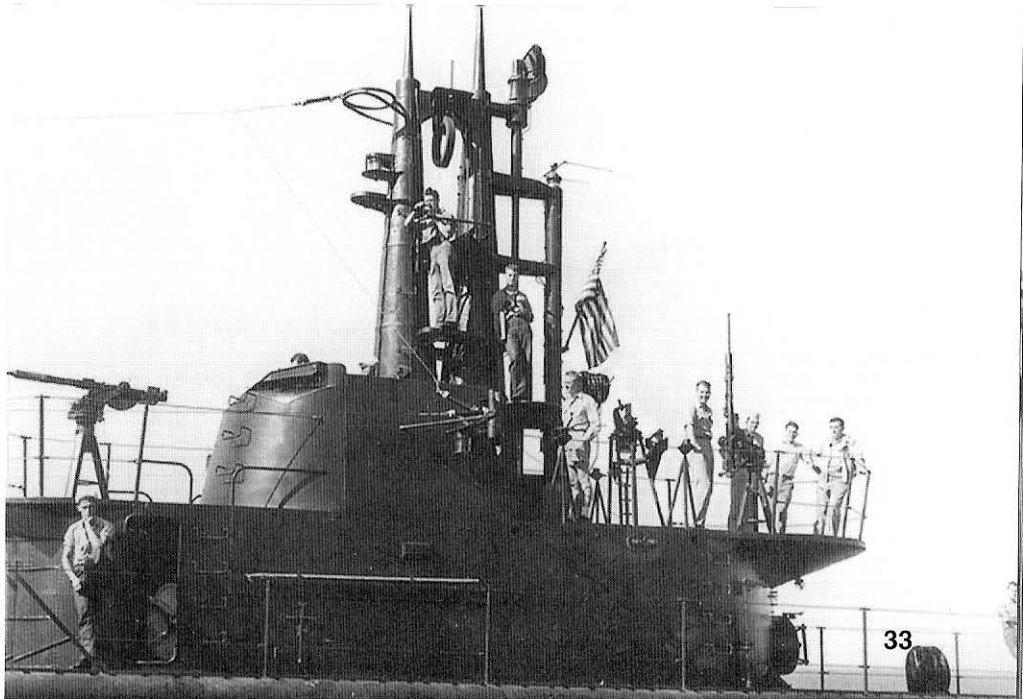
(▸▸ 37)

The low, short tower and simplified shears of this boat identify it as a *Balao*. It is part of the group seen at Midway in May 1945, displaying black tactical numbers on their towers. This boat is in as-built form, as indicated by the lack of a separate, conical mast for the SD, except perhaps for the very elaborate antenna leads that are carried from a wing-shaped spreader, around a pair of insulators, and down to the pair of lead-ins on the tower side under the aft TBT. (NARA)

Another view of *Balao* (SS 285) as modified in October 1944. She has two pintle mounts for .30-caliber machine guns at the deck edge on both sides aft of the tower. This view shows well the lack of internal framing in the new tower structure. (NARA)

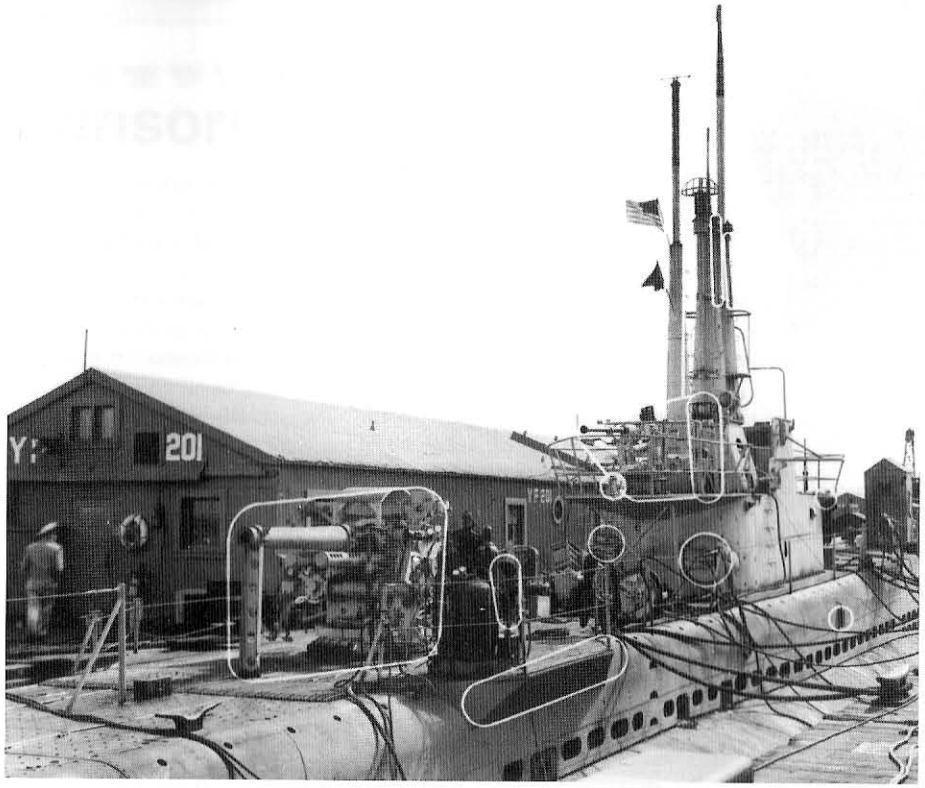


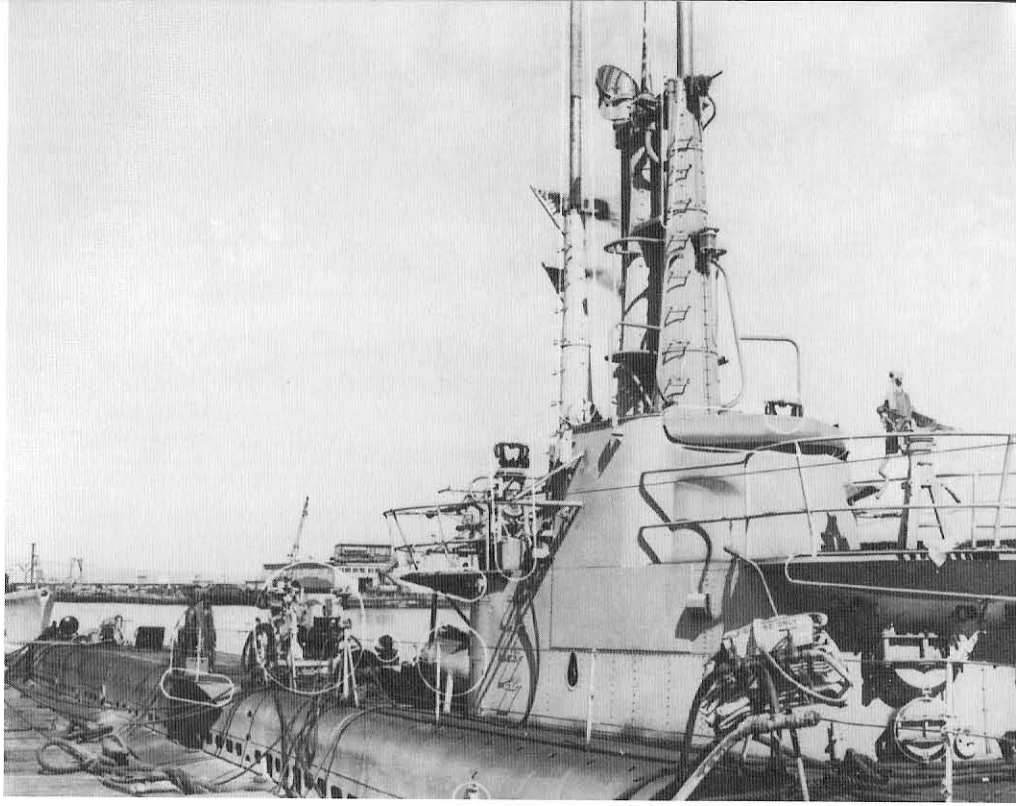
Kete (SS 369) on trials in Lake Michigan in August 1944 after completion at Manitowoc. She also has the early-series *Balao*-subclass periscope shears, with the SD antenna mast still attached to the structure. She has a low tower, although it is built to a somewhat different design than the government-built *Balao*. (NHC)



◂ *Blenny* (SS 324), seen on 21 August 1944 while working up off New York, was built at Electric Boat. A sailor on top of the shears and another at bridge level seem to be working on the white cables that appear to run from the portside antenna spreader. (NARA)

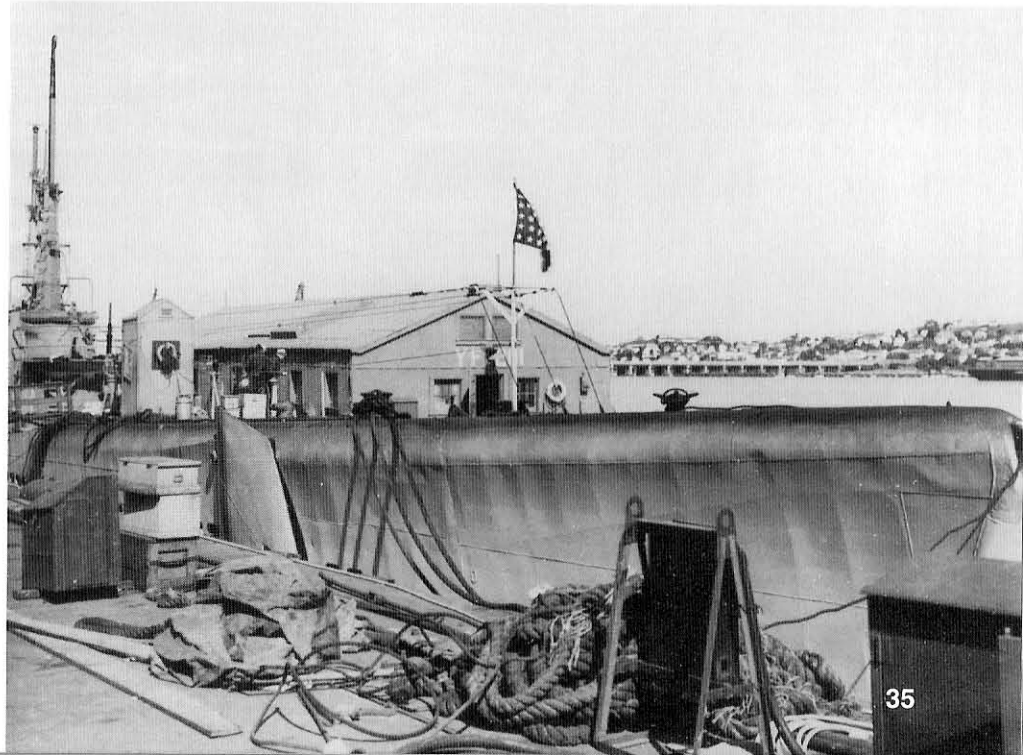
▾ Although built at a different yard, *Spikefish* (SS 404), seen here the next day, is similar to *Blenny*, but has a few interesting differences. Built at Portsmouth to the government version of the *Balao* design, *Spikefish* has the extra row of limber holes that most readily identifies government-built boats, but also has a more rounded deck casing and a tower structure cut away under the aft cigarette deck, which is supported by a post. This cutaway was not generally adopted because soon after, the much heavier 40 mm Bofors, which required a bigger and stronger cigarette deck, began supplanting the Oerlikons seen here. *Spikefish* appears to be enough lighter in tone than *Blenny* that it is possible that she was finished in the rarely seen Measure 10 (overall Ocean Gray 5-O). (NARA)





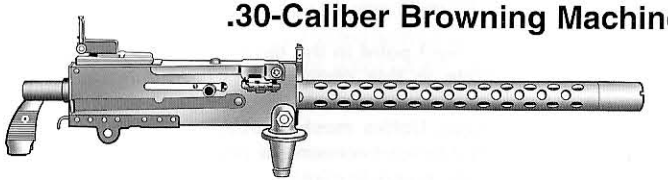
▲ *Sand Lance* (SS 381) at Mare Island, 27 February 1945, completes a major refit and repairs to damage to her stern caused by enemy bombs and a malfunctioning torpedo. She has received a 5-inch, 25-caliber mount aft of her tower. The wooden decking under the gun ends just aft of the mount. The decking from there to the stern is simply painted steel, a practice which was not common. The extended forward periscope has the late-war ST ranging radar, but she retains her mid-war SD air-search set. (NARA) (Above Right) The bulge in the bridge face common on Portsmouth-built boats is clearly delineated by *Sand Lance*'s Measure 32/9SS camouflage. Two ammunition scuttles have been added under her forward cigarette deck. The forward-pointing stub antenna on the periscope shears is for the APR-1 radar detector. (NARA)

▶ The light structure of the outer hull at the bow can be seen from the amount of dimpling between the frames. Several different shapes of bow planes were used on *Gatos*. *Sand Lance* has the more pointed variant that extended above the deck line when retracted. (NARA)



Anti-Aircraft Weapons

.30-Caliber Browning Machine Gun



▲ The numerous small limber holes that pierce the deck casing and outer hull aft can be seen well in this view of *Bowfin* (SS 287) taken at Mare Island on 28 November 1944. All visible parts of the outer hull (excluding the deck casing) were always painted dull black, regardless of the camouflage applied to the upperworks. At this time, *Bowfin* was painted in Measure 32/3SS-B — the 'light gray job' — which called for the aft end of the deck casing to be painted dull black, feathering into Ocean Gray 5-O and Haze Gray 5-H moving forward. (NARA)

◀ The hard point in the deck casing forward of the tower is clearly visible in this photograph of *Dragonet* (SS 293) taken at Mare Island, 25 March 1945. She was built by Cramps to the Portsmouth design. Unlike most *Balaos*, her DF loop doesn't hang from the upper brace between the periscope shears, but rather sits on the middle brace. (NARA)

Sensors

One factor that contributed immensely to the success of the *Gatos* in the Pacific was the superiority of American electronics, particularly radars and radar detectors, over anything the Japanese were able to deploy. Radars commonly deployed on *Gatos* during World War II were:

SD. This long-wave (2.65-meter wavelength) air-search radar was the first fitted to American submarines. By mid-1942, all *Gatos* leaving for patrol carried an SD set. It went through several production upgrades, the last being the SD-2, incorporating Identification Friend or Foe IFF), which continued in production into 1943. The antenna was initially a relatively broad single crossbar (J-type), later replaced by a much thinner split crossbar (U-type).

SJ. An S-band (c. 10-centimeter wavelength) surface search radar was first installed in June 1942 and became common on *Gatos* by the end of the year. In its early form, it used a small, solid spherical-section antenna with parallel top and bottom edges. Later versions used a somewhat larger, paraboloid open-mesh antenna with a prominent rib structure. These remained standard fit on U.S. submarines through the end of the war. The X-band (c. 4 centimeter wavelength) SS radar was just coming into service at the end of the war.

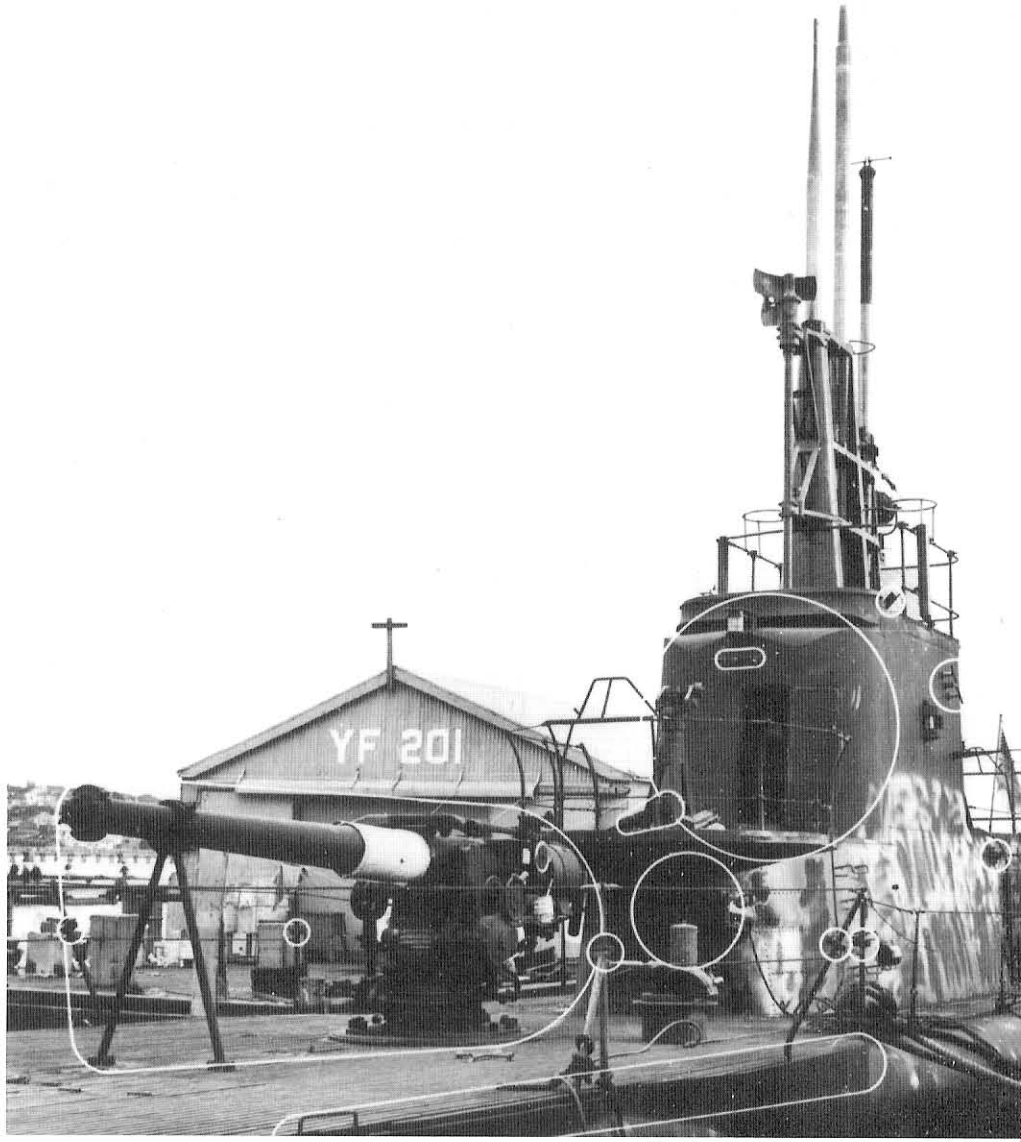
ST. An X-band surface-search set used only to establish range-to-target during night submerged attacks. The antenna was a 2-inch x 6-inch (51 mm x152 mm) panel arrayed vertically below the lens of a Type 4 night periscope. It used the same power supply as the SJ, but required a separate A-scope (line oscilloscope) display.

SV. This S-band air-search radar began replacing SDs on *Gatos* in early1945. Its antenna looked almost identical to the SJ's, except that it was approximately twice the size. Besides being more powerful, more accurate, and more reliable than the SD it replaced, it had the additional advantage of using the same display as the SJ, saving space inside the conning tower.

Shipboard electronics didn't end with radars. *Gatos* carried, and used to great advantage, an APR-1 low-frequency radar detector, which detected radar emissions at wavelengths down to 40 centimeters. A radar detector is nothing more than a radio receiver dedicated to capturing radar pulses. The APR-1 detector could intercept the Japanese Type 3 Mk 1 air-search radar, the most commonly deployed Japanese radar, which operated at a wavelength of 2 meters. Later in the war, a pulse analyzer (SPA-1) was added that identified the pulse repetition frequency (PRF) and pulse width (PW) of the emitter. Between those two numbers, a radar can generally be uniquely identified by type. To detect the late-war Mk 2 Mod 2 fire-control radar deployed on Japanese surface ships, and which operated in the shorter S-band beyond the range of the APR-1, an S-band detector, the APR-5AX/SPR-2, was deployed.

The other main sensor deployed on submarines was sonar, which could be used actively, to find the range and position of a target, or passively, simply to listen to activity around the boat. Unlike radar, sonar is continuously affected by interference from noise. Noise is reflected by the ocean's surface and the bottom and is distorted and sometimes deflected by thermal layers. Fish also produce noise and can reflect sound if present in large schools. Finally, the more noise produced by the listening boat, often a factor of its speed, the less effective its sonar will be. All these issues led the Navy to downplay the importance of sonar before the war. Tactical doctrine called for submarines to detect targets by sight or by passive sonar and to use active sonar, if at all, only in single pings to establish the range of targets already located by other means. In actual combat, captains were reluctant to use active sonar even in this very limited fashion, as it advertised a boat's presence to anyone within range of the sound.

That standard sonar on most *Gatos* throughout the war was the WCA, originally fitted only under the bow. Starting in late 1942, units were added above the outer deck forward, (▸▸ 38)



▲ ***Hake*** **(SS 256) is seen here on 30 November 1943, prior to her first Pacific patrol. She completed two anti-submarine patrols in the Atlantic with no success, before being transferred west. She shows a typical mid-war electronics outfit with one notable exception: she has the expected SD and SJ antennas, but also has a very unusual set of 'turnbuckle'-shaped antennas mounted on her tower. They look like a rod mounted on three short posts, and four of them are fitted to cover the four sides of the tower. Three can be seen in this view (each circled in this Mare Island photograph): one mounted horizontally on the front face of the bridge above the open door, one mounted at a 45-degree angle on the side of the tower, and one mounted on a mesh screen support facing aft, partially visible just above the edge of the venturi and below the searchlight, also mounted at an angle. The purpose of these antennas is not known, but it is possible they are an early version of the directional DBU antenna for the APR-1 radar detector. (NARA)**

▲ Three crewmen string up victory pennants on *Batfish* (SS 310) at Pearl Harbor, 3 March 1945. The later model SJ antenna, an open paraboloid is just forward (to the right) of the late-model SD antenna. The APR-1 stub antenna faces forward next to the middle sailor. The aft TBT is below the elbow of the sailor to the left. (NARA)

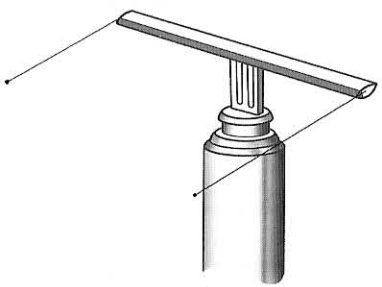
because the under-bow units had a tendency to get damaged if the boat bottomed. This sonar could be used in active or passive mode and, when used actively, could give some idea of the bearing of a target using bearing deviation indication (BDI) and a split sonar beam. The idea was that the captain would 'calibrate' the stadimeter built into the attack periscope using a single ping from the WCA. (A stadimeter allows the distance of an object of known height to be determined by bringing two images into coincidence. The less accurate the estimation of the height of the object, such as a ship's mast, the less accurate the calculated distance. Using the WCA to accurately determine the distance, the captain could then use the stadimeter to measure the height of the target's mast and, that being now known accurately, he would thereafter be able to determine the object's range using the stadimeter only.) In passive mode, BDI offered little benefit, because the sensors designed to read the split-beam were too close together.

Needless to say, the WCA wasn't terribly popular with submarine commanders. The *Gatos* didn't have an effective passive sonar until the JP line-array was introduced mid-war. This was a 'T'-shaped device, similar in operation and appearance to the German KDB (Kristalldrehbasis Gerät – rotating baseline sensor device). Both devices featured a number of individual sound receivers arrayed along the crossbar of the 'T' wired such that the time between receiving a sound at individual sensors could be used to determine the position of the source relative to the axis of the crossbar. By rotating the device, a source's bearing could be precisely determined. The Germans had developed the KDB between the wars, and all U-boats leaving on patrol had one fitted when the war began in 1939. Despite being very accurate in locating sound sources, they rapidly fell out of favor because they couldn't be used at any but the slowest speed and were extremely fragile, being easily disabled by depth charging or even deep diving. When the Americans deployed the JP, they rapidly discovered it suffered from the same defects. Nevertheless, JPs were fitted to all new and refitted *Gatos* starting in 1944. An improved model, the JT, with a crossbar 5 feet (1.5 m) long rather than 3 feet (.91 m) long was introduced in mid-1945.

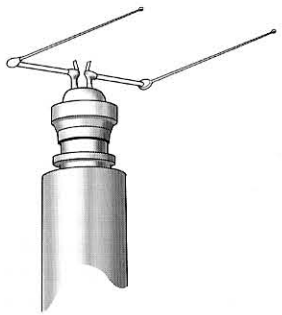
Both WCA and JT were to be replaced by the WFA, which consisted of a single transducer mounted below the boat's bow and a linear array of three transducers in a cylindrical dome on the boat's foredeck. At least one boat, *Conger* (SS 477), is known to have been completed with a WFA installation before the war ended. However, despite being commissioned in February 1945, she was retained at New London for extensive testing before being released for combat at the end of July. She was en route to Pearl Harbor when the war ended. (▸▸ 42)

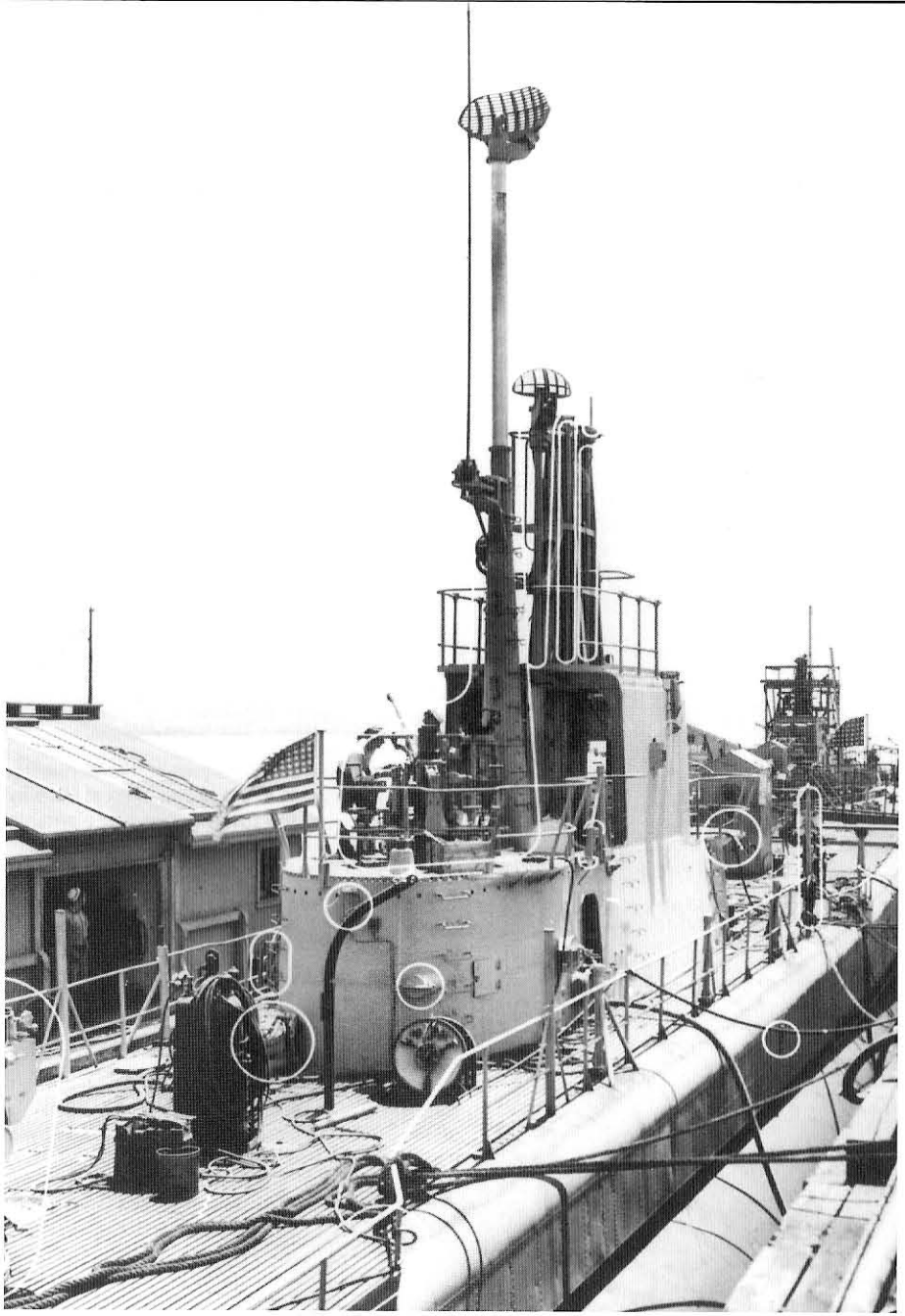
Radar Antennas

Early SD antenna

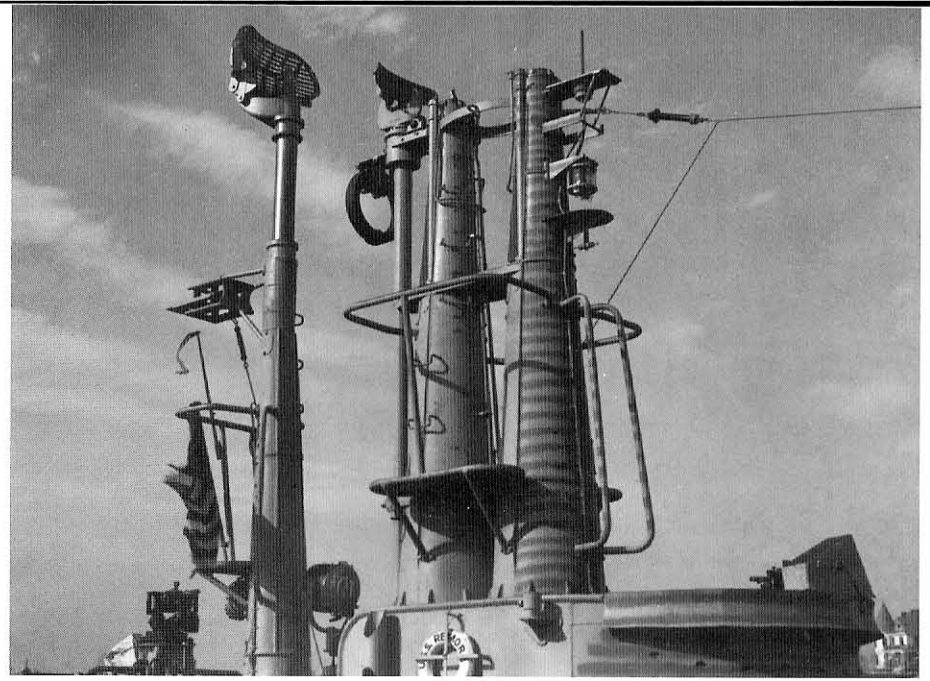


Late SD antenna



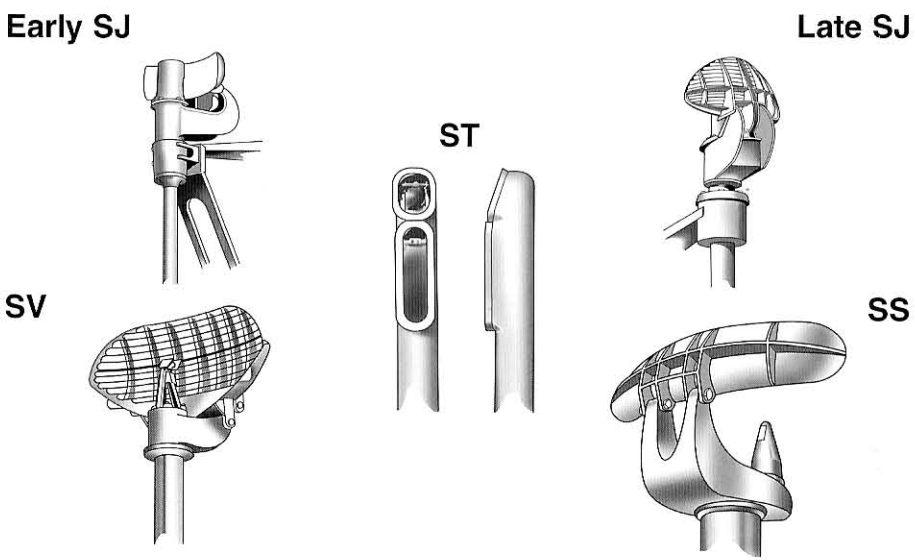


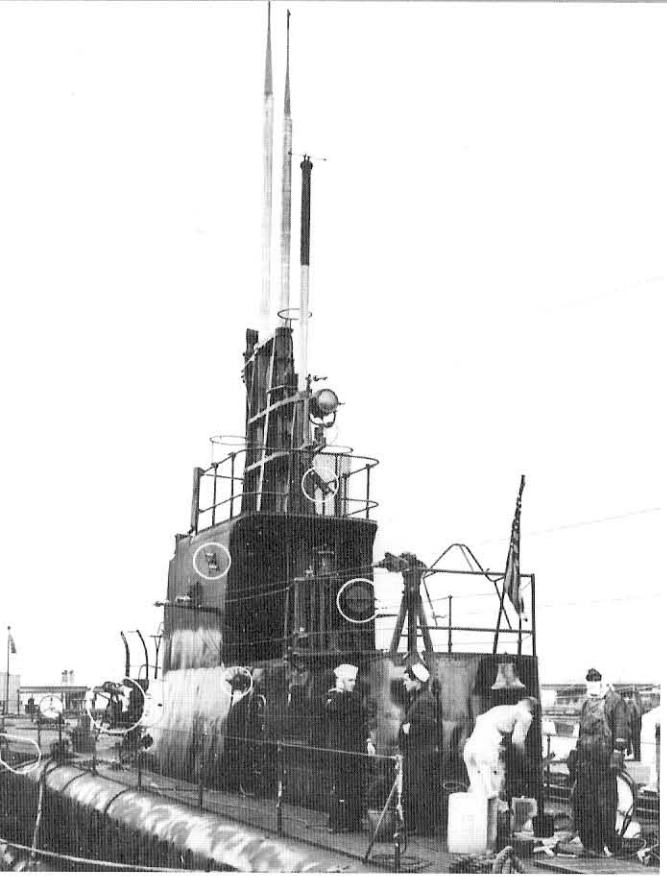
▲ *Mingo* (SS 261) shows off a very late-war electronics suite at Mare Island, 17 July 1945. Besides the later SJ antenna next to the periscope shears, she has the larger, but similarly shaped, SV antenna that replaced the SD on the extendible mast and, aft of that, the new whip antenna for HF communications. *Mingo* is unusual in that she retained the taller tower structure of the *Gato*-subclass. (NARA)



▲ *Remora* (SS 487) is seen soon after the end of the war on 7 February 1946, less than a month after her commissioning. The most obvious change from *Mingo* is the replacement of the later SJ with the SS antenna as the sea-search radar. The larger antenna to the left is the SV. The aft TBT is below the flag to the left. (USN)

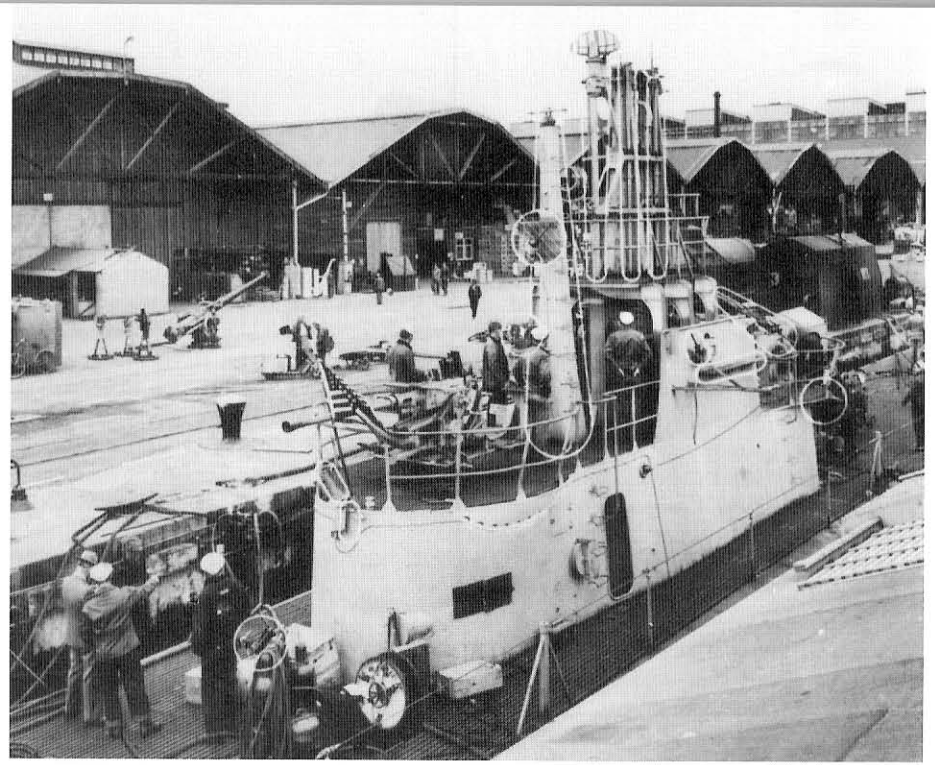
Radar Antennas





◂ Another view of *Hake* (SS 256) on 30 November 1943, showing the early attempt at a directional radar detection antenna. The aft facing 'turnbuckle' is mounted on a wire mesh grid. This appears to be part of the antenna and is perhaps a reflector of some sort. (NARA)

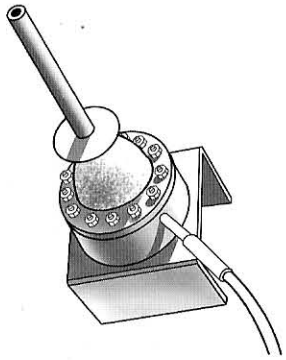
▸ The same boat at the same yard, exactly seventeen months later. Much has changed in *Hake*'s appearance. Her tower has been cut down, a free-standing radar mast has been added aft of the shears, SV radar has replaced SJ, and the directional ESM antennas have been replaced with what looks like APR stub antennas set on the side of the tower at an angle aft of the radar mast. (NARA)



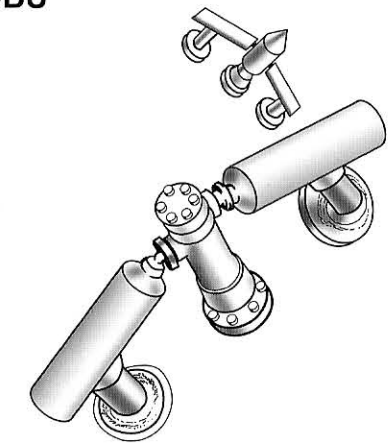
▾ The ultimate ESM antenna for directional radar detection was the two-part DBU antenna set seen here on the side of the tower of an unidentified boat, part of the group seen at Midway in May 1945 characterized by tactical numbers painted on the towers. The two elements were set at right angles to each other; the larger element was for lower frequencies. These look like they might have been derived from the 'turnbuckles' seen earlier on *Hake*. (NARA)

Radar Detection Antennas

APR



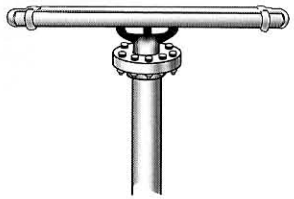
DBU



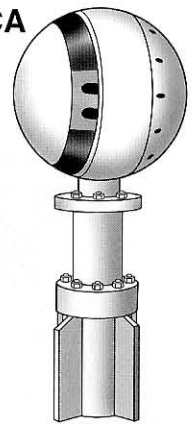
▸ *Bowfin* (SS 287) is seen at Mare Island with both a JP and WCA sonar on deck on 28 November 1944. The JP was a passive directional array with a 3-foot (0.91 m) crossbar; the WCA was an active sonar housed in a spherical 'head,' mounted on a pedestal above the deck. In this view, the WCA's head is lying to the side of the pedestal, ready to be mounted. The WCA was rarely seen on U.S. submarines before the end of the war. (NARA)

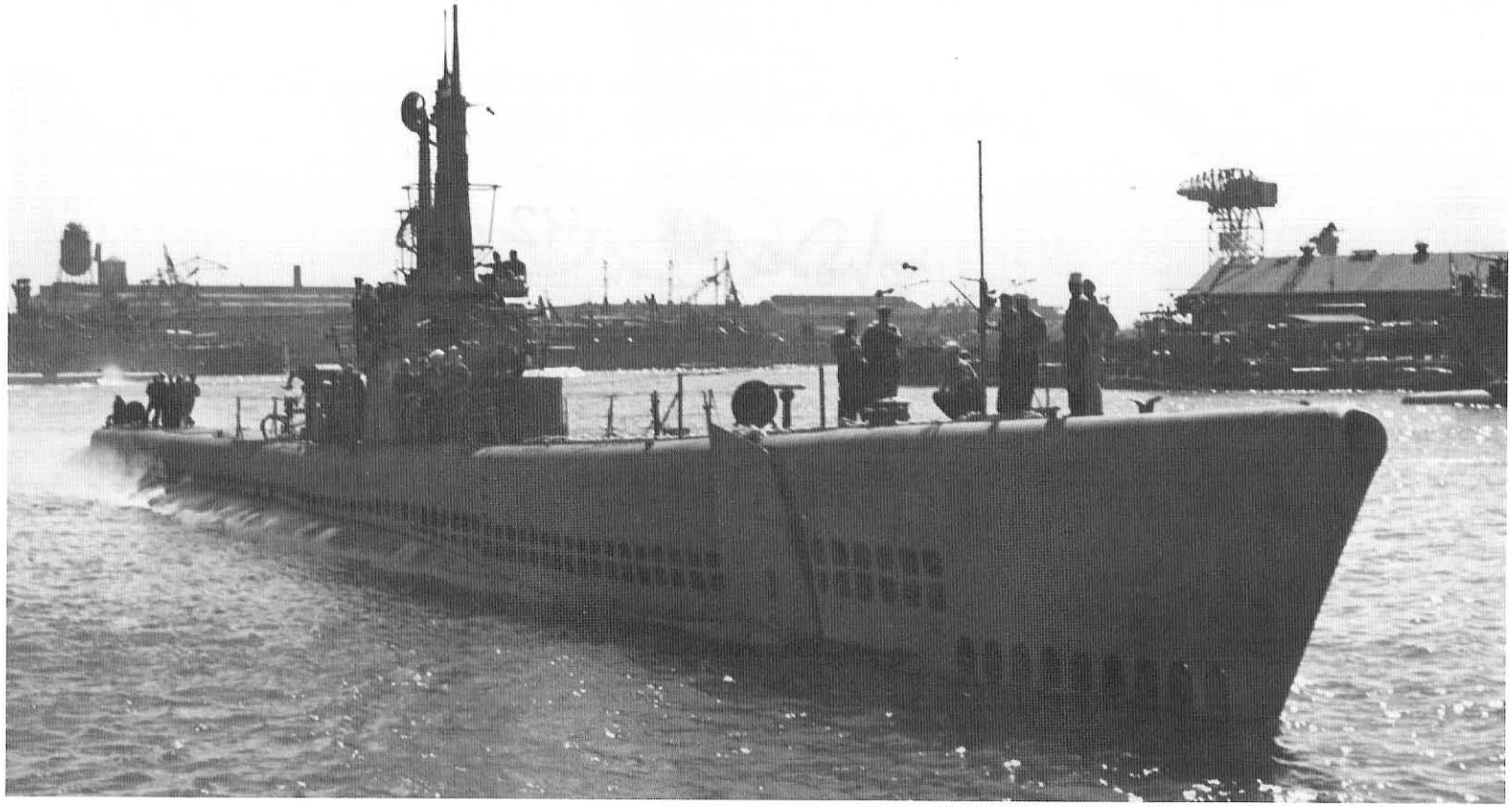
Sonars

JP



WCA





▸ ***Diablo*** **(SS 479) enters Pearl Harbor in late July 1945. She left on her first operational patrol in August, but the war ended before she reached her assigned sector. She is a *Tench*, but it is impossible to distinguish her from a late *Balao*. She has extra limber holes forward of the bow plane, a feature of some later *Balaos*. This boat also carries a black tactical number on her tower, obviously painted in gloss black, given the reflection of light off the numerals. (NARA)**

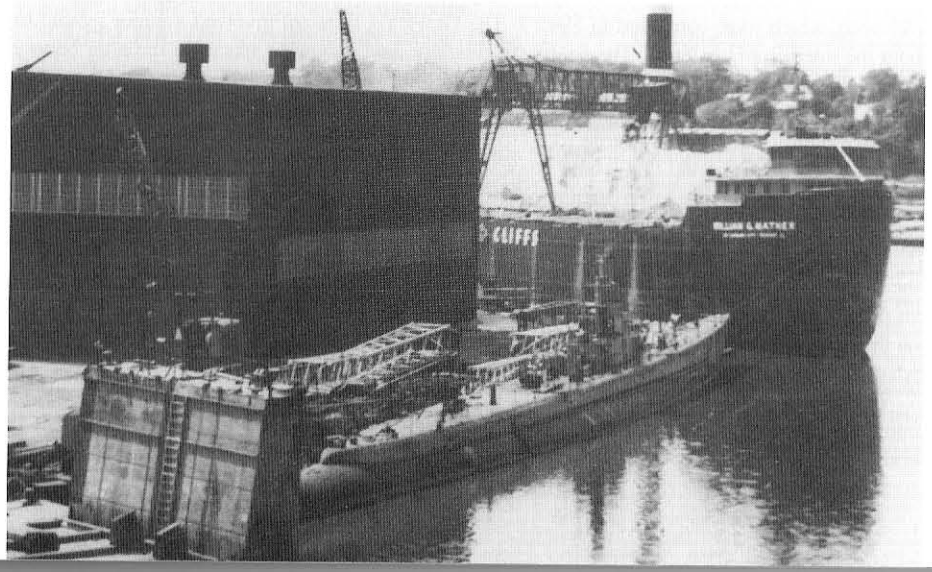
The *Tench* Sub-Class

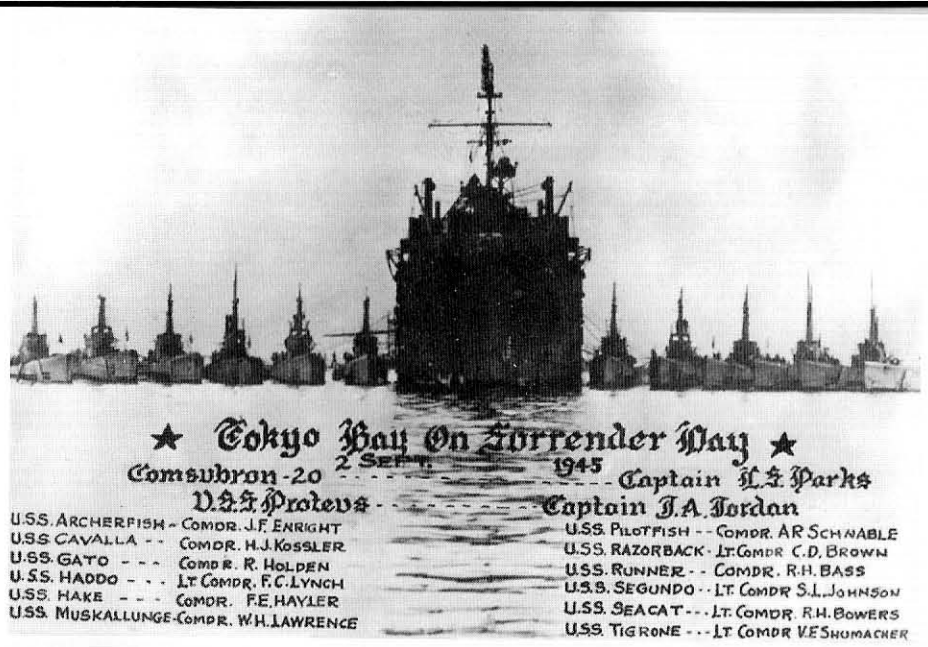
The final sub-class was named for USS *Tench* (SS 417). She and 145 sisters were authorized in FY 1943 and subsequent supplemental budgets, with 113 orders actually going to Portsmouth Naval Shipyard (forty-nine boats), Cramp Shipbuilding (ten boats), Electric Boat (forty boats), Mare Island Naval Shipyard (six boats), and the Boston Naval Shipyard (eight boats). The first *Tench* was laid down at Cramp in August 1943, but most were cancelled before they could be started. In all, only thirty-one *Tench*-class boats were actually completed. Of those, four were suspended after launch, but were completed between 1948 and 1951 as GUPPYs. (Four additional boats were launched, but were never completed, either being used as test hulks or scrapped in incomplete state.) The first *Tench* in commission was the name boat, which joined the fleet on 6 October 1944 at Portsmouth. All told, twenty-seven *Tenches* were actually completed as designed, all but four of those coming from Portsmouth. Of those, only eleven made patrols during World War II, and none of those were lost.

The *Tenches*, like the *Balaos*, were indistinguishable externally from the preceding sub-classes. Internally, the changes from the *Balaos* involved the rearrangement of the tanks in the double hull so that internal piping was rationalized and simplified. One former ballast tank was turned into a fuel tank, which increased fuel capacity to 113,510 gal (429,683 l) and increased range to 16,000 nautical miles at 10 knots. Perhaps even more significant was the change to direct-drive electrical motors. The reduction gears used to drive the propellers were one of the major sources of noise on the boat. While the gear 'whine' was drowned out by the noise of the diesels when the boat was on the surface, when the boat was submerged, it was the single greatest source of noise. A team of engineers led by Capt. Hyman G. Rickover developed a double-armature motor, which replaced two of the standard high-speed motors and the gearbox. First tested on one of the last *Balaos*, *Sea Owl* (SS 405), it proved highly successful and was adopted for the *Tench* class. (Rickover remained at the forefront in the development of submarine propulsion systems, leading the development of nuclear-powered submarine USS *Nautilus*.)

All *Tenches* built to the original design had a lower, cut-down tower structure and simplified periscope shears with a separate, faired extendable radar mast aft of the shears for the large SV air-search radar antenna which replaced the earlier SD. (Standard practice was to raise the antenna like a periscope and sweep the sky before the boat surfaced.) The SJ, which remained the standard sea-search set, had its antenna mounted on a fixed-length pole mast most often set just behind the shears, forward of the SV mast. All *Tenches* carried single 40 mm Bofors mounts on the two cigarette decks. The standard deck gun was now a 5-inch (127 mm), 25-caliber mount. At the captain's discretion, the boat could carry two such mounts, one forward and one aft of the tower. More often, only a single such mount was carried. In that case, it was not unusual for a single 20 mm Oerlikon mount to be fitted at the empty hard point on the deck. It was also the captain's discretion where the deck gun(s) would be sited. These changes were made to earlier *Gatos* and *Balaos* as they underwent late-war refits, so didn't uniquely distinguish the *Tench*-class boats from earlier boats. (▸▸ 44)

▾ A veteran of fourteen war patrols, *Silversides* (SS 236) served on into the peace. She was placed in reserve in 1946, but was recommissioned as a training boat for reservists based in Chicago and served in this capacity until 1969. She is seen here at Manitowoc, the birthplace of many of her sisters. (SFL)

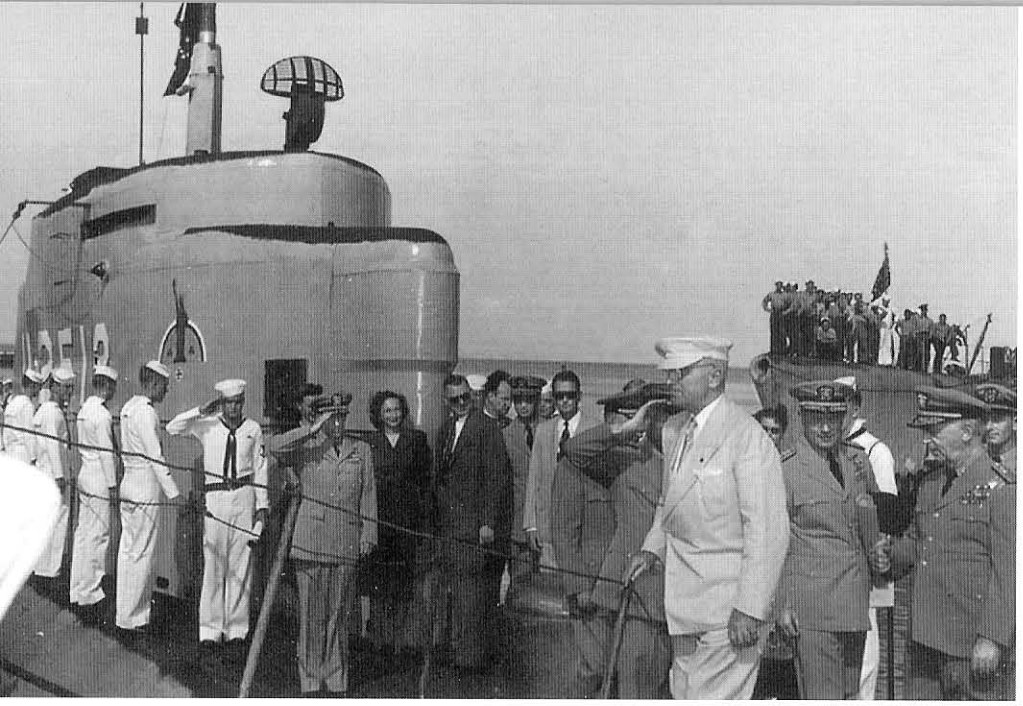



★ Tokyo Bay On Surrender Day ★
Comsubron-20 2 Sept. 1945 Captain L.S. Parks
U.S.S. Proteus - Captain J.A. Jordan
U.S.S. Archerfish - Comdr. J.F. Enright
U.S.S. Cavalla - Comdr. H.J. Kossler
U.S.S. Gato - Comdr. R. Holden
U.S.S. Haddo - Lt Comdr. F.C. Lynch
U.S.S. Hake - Comdr. F.E. Hayler
U.S.S. Muskallunge - Comdr. W.H. Lawrence
U.S.S. Pilotfish - Comdr. A.R. Schnable
U.S.S. Razorback - Lt Comdr C.D. Brown
U.S.S. Runner - Comdr. R.H. Bass
U.S.S. Segundo - Lt Comdr S.L. Johnson
U.S.S. Seacat - Lt. Comdr. R.H. Bowers
U.S.S. Tigrone - Lt Comdr V.E. Shomacher

▴ The war ended abruptly, but there had been no doubt about the outcome for some time. It was altogether appropriate that a squadron of *Gatos* was present in Tokyo Bay in time for the formal surrender. It was even more appropriate that one of those boats was *Gato* herself. (NHC)

◂ An officer leans on the jackstaff as *Cero* (SS 225) docks, probably at Pearl Harbor, and probably near the end of the war. An unusual feature, not seen on other boats, are the cables running from the bow back to the tips of the bow planes. These were most likely intended to prevent fouling of the planes. The unidentified boat to the left has a black tactical number on her tower, as seen in back areas of the Pacific toward the end of the war. (NARA)

▾ *Sea Owl* (SS 405), seen here in early 1951, completed three patrols before war's end. Her electronics appears to be standard very-late war, with SS and SV radars and the JT sonar, distinguished from the wartime JP by the longer crossbar. She has a flat-panel windscreen erected in front of the bridge to provide minimal protection. By this point, the standard camouflage had reverted to overall black. Soon after this photograph was taken, *Sea Owl* was converted to a Fleet Snorkel boat, in which form she served until stricken in 1969. (USN)



▲ **President Harry Truman departs *U 2513*, one of two German Type XXI U-boats which were transferred to U.S. Navy control after the war, 5 December 1947. These boats came as a revelation to the Navy, which had been planning to simply build an enlarged *Gato* after the war. Except for the removal of the remote-control twin anti-aircraft turrets at the forward and after corners of the tower, the addition of an SJ radar, and the shiny new paint job, *U 2513* looked just as she appeared in German service. (NHC)**

Postwar Conversions

Of the 351 *Gatos* to be ordered during the war, 222 were completed to the original plan as fleet boats. Almost all the rest were cancelled, as by mid-1944 it was obvious how the war would turn out and that there were more than enough fleet boats to assure victory. Of the boats not finished as fleet boats, eight were not cancelled outright. They'd been launched and were at various stages of fitting out. It was decided to leave those boats in an unfinished state. The Navy wanted a chance to catch its breath and see what the postwar world might look like.

One thing that was obvious was that submarine technology had evolved dramatically in the Atlantic while the Navy had been looking to the Pacific. Nothing more perfectly embodied these changes than the Type XXI U-boats the Germans began building in 1944. The Americans acquired two Type XXIs as spoils of war (*U 2513* and *U 3008*). When the Navy began testing the two captured boats, more than a few eyes were opened.

Even before the war, the Germans had realized that their main U-boat types, which were simply incremental improvements of World War I designs, would likely become vulnerable to improved Allied defenses at some point in the war. Therefore, they funded the work of the visionary designer, Dr. Helmuth Walter, who proposed a revolutionary new type of submarine based on a 'closed-cycle' propulsion system using the breakdown of hydrogen peroxide as a source of heat and oxygen to run a turbine engine. The system proved difficult to perfect, but plans were put in place to build a large number of operational Walter boats, designated Type XVIII by the Germans. This was a boat of a size equivalent to a *Gato*, but with a deep, highly streamlined hull designed to reach a submerged speed of 24 knots, faster than nearly all the convoy escorts used in the war. The pressure hull was a 'figure-8' arrangement of two partial cylinders mated one on top of the other. The upper portion was for all crew spaces, weapons, and machinery, while the slightly smaller lower hull was for hydrogen peroxide tanks.

The U-boat offensive in the Atlantic collapsed in May 1943, long before the Type XVIII was ready for mass-production. Searching for any solution that would be available in the short-term, German engineers decided to mate the new hull with a conventional powerplant, using the capacious lower hull to store a vastly increased number of battery cells, enough to drive two large electric motors of 2,500 hp each. While this wouldn't give the spectacular performance expected from the Type XVIII, it still produced a boat capable of reaching 17.2 knots submerged and sustaining 6 knots for two days. To this capability was added a revolutionary passive sonar, the Balkon Gerät, capable of detecting and tracking multiple underwater targets at more than 5 nautical miles, far beyond the capability of the contemporary American WFA sonar. It is fortunate for the Allies that the Type XXI came into service too late to influence the war's outcome.

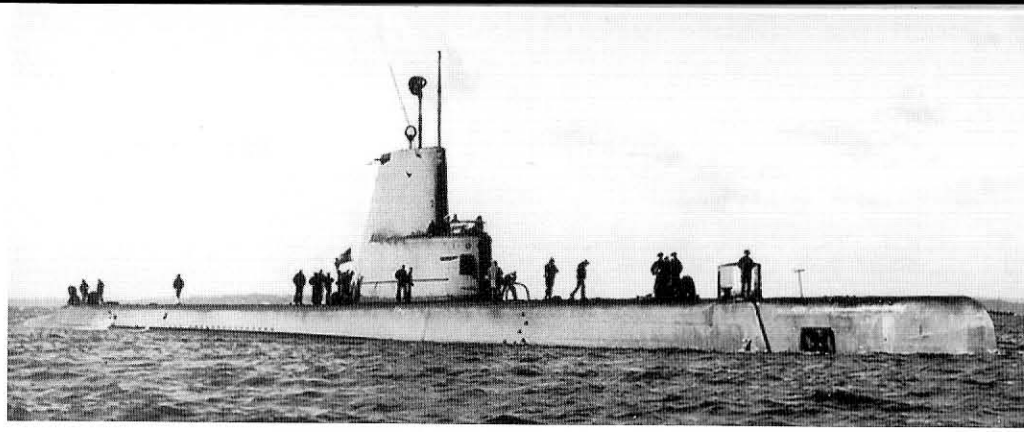
Certainly, the Americans understood, as they put their captured U-boats through their paces in 1946, that their huge fleet of nearly two hundred operational *Gatos* was effectively made obsolete by these two boats. The Navy would have liked to replace all its fleet submarines with boats with Type XXI-like capabilities, but the funds simply weren't available. A new class of submarines was designed incorporating these features, and money was authorized, beginning in 1948, but ultimately only six *Tang*-class boats were funded, the first one entering service in 1951. Clearly, this wouldn't satisfy the need for a significantly upgraded submarine fleet, especially given that the Soviets had no similar money constraints and produced 215 somewhat smaller *Whiskey*-class boats, which began entering service the same year as the first of the *Tangs*. The only option was to upgrade the existing *Gato*-class hulls, a solution for which Congress was much more willing to provide funding. Thus *Gatos* began entering refit yards in 1946, to emerge in a bewildering variety of shapes and designations. The following are the major modifications to the *Gato* design in the years following the war.

GUPPY. The acronym stands for Greater Underwater Propulsive Power (the 'Y' was added just for the sake of pronunciation). There were six distinctly different main GUPPY conversions with many minor variations even within a particular conversion type. These were:

GUPPY I. The first GUPPYs were a pair of *Tench*-class boats, *Odax* (SS 484) and *Pomodon* (SS 486), which were converted in 1946-7. The GUPPY I standard involved a major rebuild to both the interior and exterior. The pantry, refrigerator, and magazine spaces in the after battery compartment were removed or relocated, and the number of battery cells was doubled from 252 to 504. The batteries were of a new design which used more and thinner plates, allowing the battery to hold a significantly greater charge. Plans to install snorkels were shelved, because the Navy had not yet perfected a snorkel that would work with the two-cycle diesels used in these boats. The bow was rounded and the tower streamlined so dramatically that the term 'sail' became the new name for the structure built up around the conning tower. The deck gun was removed and any other deck clutter either deleted or made retractable. One of the two periscopes was removed to make the shears smaller and easier to streamline. They were given the large chin-mounted BQR-2 sonar, an Americanized Balkon Gerät. The effect was remarkable. *Pomodon* was able to make 17.8 knots on the surface, down from 21 knots, but submerged, she could make 18.2 knots, more than double what an unmodified *Gato* could do.

GUPPY II. So successful was the GUPPY I conversion that the Navy immediately planned to convert a large percentage of the existing *Gato* fleet. Money constraints limited GUPPY II conversion to twenty boats, but a few more GUPPYs were added when Congress approved

▲ ***Pickerel*** **(SS 524) was one of the boats left incomplete at the end of the war but finished in 1949 as a GUPPY. Originally a *Tench*-subclass boat of government design, she has the 'Portsmouth Sail' with square portholes in the bridge and a rounded after edge. The top part of the very narrow upper sail was bulged out to store retracted radar antennas. (NHC)**



▲ **In contrast to *Pickerel*, *Cochino* (SS 345) has the 'Electric Boat Sail' with round windows, a straight trailing edge, and a thicker upper portion to house radars. The dome on her foredeck was for a WFA single-ping ranging sonar. *Cochino* was lost soon after this picture was taken in 1949 in an accident while on one of the Cold War's first spy missions. (NHC)**

completing four of the eight suspended hulls as GUPPYs as well. The GUPPY II differed from the earlier standard by including a now-perfected American snorkel and retaining both periscopes. This required a larger sail, which existed in at least three distinct variants. If necessary, the older, high-speed electric motors were replaced by the larger, direct-drive models. The only complaint against these boats was that the crew accommodations had become extremely cramped, even after one set of torpedo reloads was deleted.

GUPPY IA. The only problem with the initial GUPPY conversions was their expense. To obtain the number of upgraded submarines the Navy wanted, it was necessary to develop a scaled-down, less-expensive conversion scheme. This conversion excluded the extensive internal modifications, simply replacing existing batteries with a slightly-improved version of the 1930s-vintage model used in the wartime *Gatos*. The net result was a boat that was almost as fast, reaching 15 knots submerged, and significantly less expensive. Ten boats were ultimately converted to this standard. Externally, they looked like GUPPY IIs.

GUPPY IB. These four boats were intended for transfer to foreign navies, two to Italy and two to the Netherlands. They received internal modifications similar to the GUPPY IA standard, but not the upgraded sensors. The two Italian boats were the only thin-hull, *Gato*-subclass boats to undergo GUPPY or Fleet Snorkel conversion.

GUPPY IIA. This conversion was similar to the GUPPY IA, except that habitability was improved by removing one of the diesels from the forward engine room and replacing it with added air conditioning. Seventeen boats were converted to this standard.

GUPPY III. The better, albeit much more expensive, solution to the overcrowding in GUPPY IIs was the GUPPY III , which added a hull extension forward of the control room. The test boat was *Tiru* (SS 416), a GUPPY II which had a 12.5-foot (3.8 m) hull section added. Still very crowded, because the added length was given over to electronics, *Tiru* had one diesel removed as in the IIAs. Eight more GUPPY IIs were converted to this standard. They differed from *Tiru* in having a longer added hull section of 15 feet (4.6 m). These boats retained all four diesels.

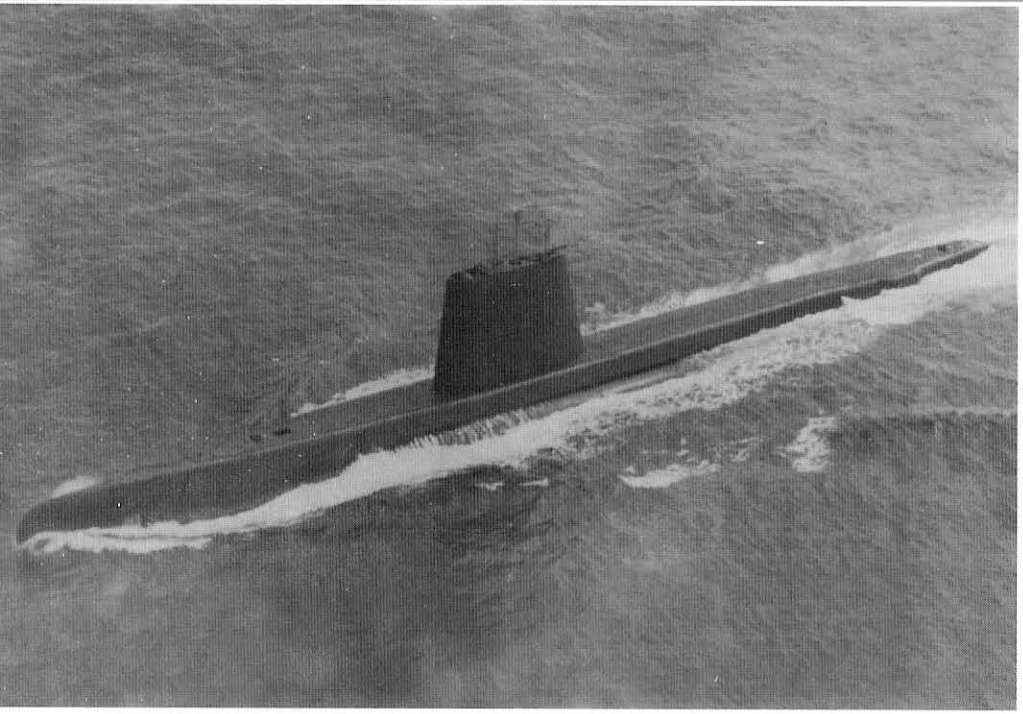
Fleet Snorkel. Even the scaled-down GUPPY IA and IIA programs cost too much for Congress, so a separate, even more limited conversion called the Fleet Snorkel Program was defined. These boats had few of the external changes associated with GUPPYs, but did lose their deck guns eventually and had streamlined sails added to house the snorkel. Internal changes were limited to increased air conditioning and the more powerful slow-speed electric motors, space for which was obtained by removal of the auxiliary diesel engine. Twenty-six boats were so modified.

SSR. These were submarines modified to carry advanced air-search radars. The value of radar pickets had been proven during the Okinawa campaign, but the losses among the radar picket destroyers deployed there had been horrendous. Thus the idea arose of mounting powerful radars on submarines which could spot incoming air attacks and then submerge to avoid retribution. At least three different radar suites, code-named MIGRAINE I, II and III, were fitted to these boats. Some SSRs had a 30-foot (9.1 m) section added to the hull forward of the conning tower to house the radars' electronics.

SSK. The notion that submarines were the best weapons against other submarines emerged as an inevitable consequence of wartime experience and awareness of the vastly improved sensors available postwar. The Navy actually designed and built the lead ships of what it hoped would be a large class of small submarines designed specifically as 'killer' submarines: SSKs. However, they proved to be more expensive and less useful than hoped, and it was obvious that the hundreds of boats necessary to form a barrage against a Soviet 'breakout' into the open oceans would have to be acquired by means other than new construction. The only solution was to convert *Gato*-class boats. Seven *Gatos* were rebuilt as SSKs, with various configurations of sonars, most notably the large BQR-4, an enlarged BQR-2, wrapped either around the sail or the bow. Eventually, all Navy attack submarines had an anti-submarine role, and the separate SSK designation was dropped in 1959.

Gunboats. Though not given a separate designation, a number of *Gatos* were modified as surface gunboats. It always had been an option during World War II for *Gatos* to carry two large deck guns, and some boats were known to have gone to war with a pair of 5-inch, 25-caliber mounts. The firepower was impressive, and the Navy came to believe that intentionally configured submarine 'gunboats' would be useful. To make a *Gato* into a gunboat, a stable element and a gun mount repeater, essentially a destroyer-style gun director lacking only the optical rangefinder, were installed. *Sea Cat* (SS 399) was the prototype for this configuration and was considered successful enough to lead to the conversion of six other boats.

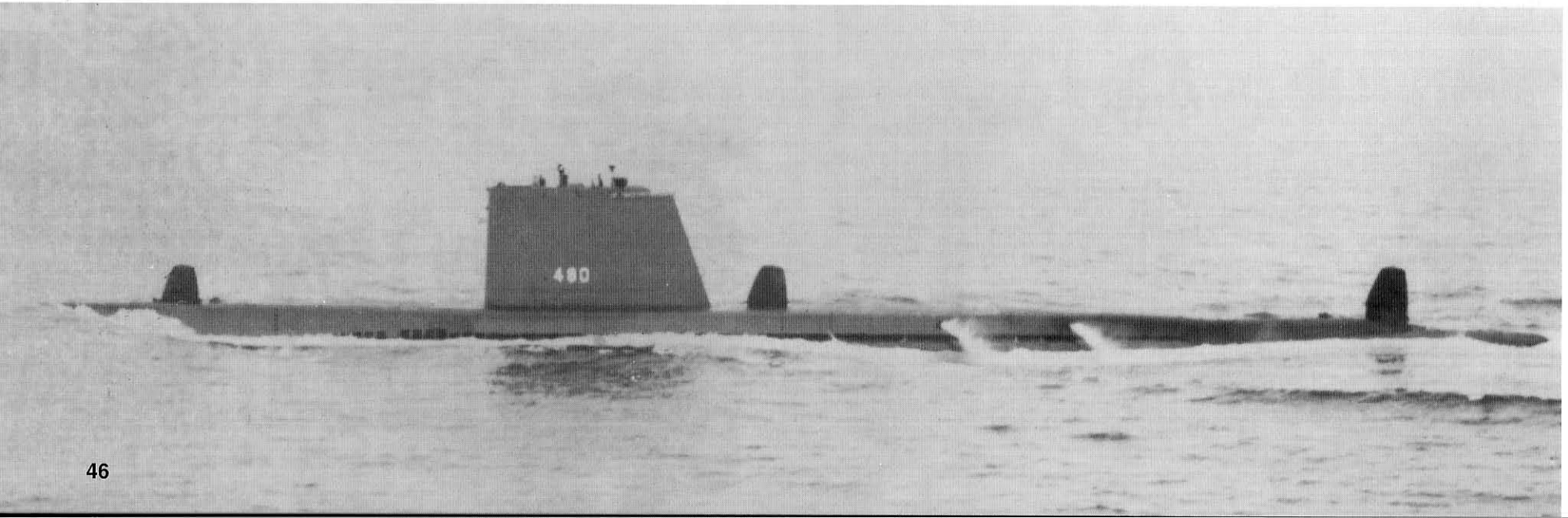
This is not a complete list, as there was also at least one SSO (a submarine modified to refuel seaplanes), an SSA (a cargo submarine), several SSGs (modified to fire Regulus missiles), at least three SSPs (designed to carry troops), and multiple AGSSs (submarines reduced to non-combatant training and support roles). Many served well into the 1960s and even later. The last U.S. Navy *Gato* in commission was *Tiru* (SS 416), taken out of service on 1 July 1975, more than thirty years after being laid down. Some served in foreign service long after that. A number have become memorials and live on as tourist attractions.



▲ An unidentified GUPPY, probably a GUPPY IIA conversion, with the 'Northern Sail.' American submarines were now going regularly into seas far unfriendlier than the South Pacific, and the height of this sail was intended to overcome a problem with the other two GUPPY sail designs, which were wet in heavy weather. The bulge in the deck casing on the portside aft covered the former location of a fourth diesel exhaust. (via Bill Crouch)

▲ The ultimate GUPPY form was the GUPPY III conversion. The most easily recognizable feature of these boats was the three-blade BQG-4 PUFFS passive ranging sonar. Comparing the signals from the three receivers allowed very accurate triangulation of sound sources. *Pickerel* (SS 524), seen earlier as a GUPPY II, was converted to GUPPY III configuration in 1962. In 1972 she was transferred to Italy, where she served until 1981. (USN)

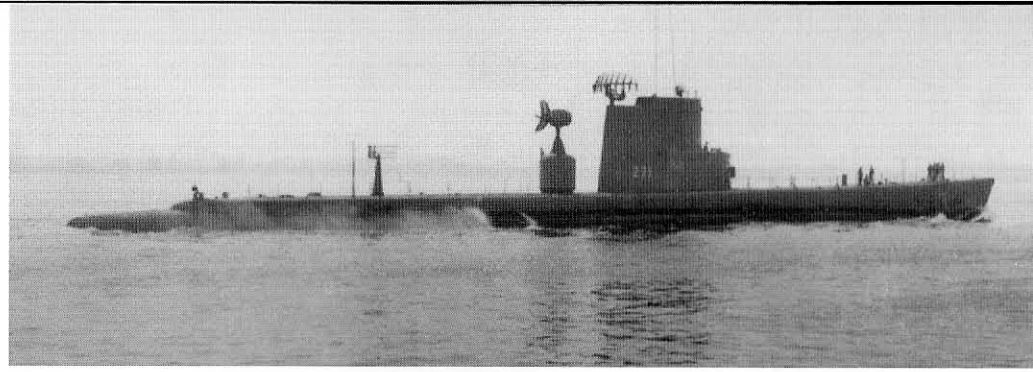
▼ *Volador* (SS 490) shows another feature of GUPPY IIIs. The tall 'Northern Sail' was lengthened 5 feet (1.5 m) to accommodate an enlarged conning tower. She was also transferred to Italy in 1972. She was stricken in 1977 and scavenged for parts to keep other Italian Gatos operating. (via Bill Crouch)



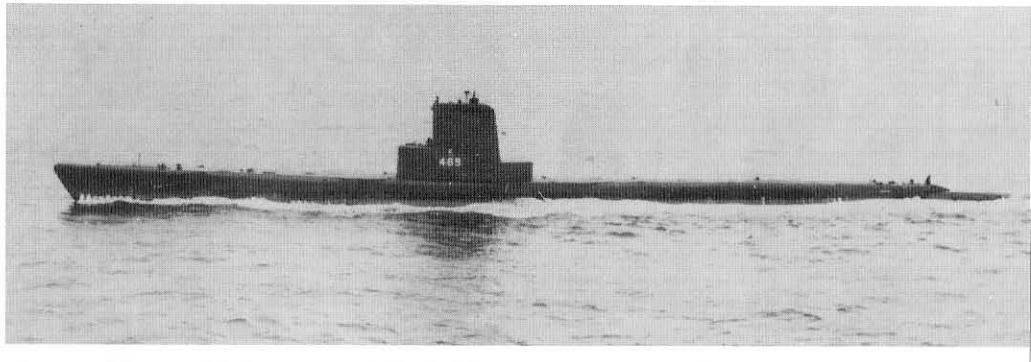
▲ The Fleet Snorkel Program was the minimal postwar conversion for *Gatos*, one that gave them little more than a new sail with a telescopic snorkel and some upgraded internal systems. *Torsk* (SS 423) was converted to this configuration in 1952. One interesting feature is the large Plexiglas half-dome over the open bridge, allowing some protection against heavy weather. She is seen here off Hampton Roads, 16 January 1965. She was retired in 1971 and has been put on display as a memorial in Baltimore. (USN)

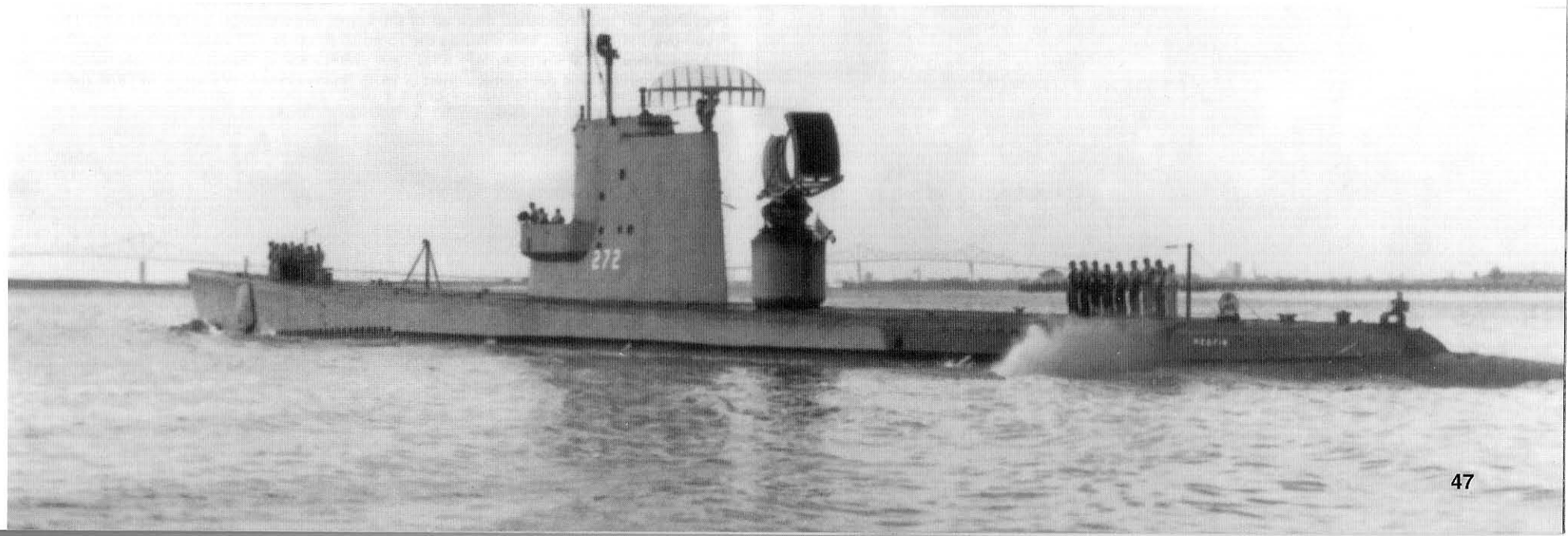
▶ All ten SSRs were stripped of their radars at the end of the 1950s. Some returned to normal attack submarine duties. *Spinax* (SS 489) served until 1969, retaining the unusual sail form of her MIGRAINE II conversion but not the large antennas. (via Bill Crouch)

▼ *Redfin* (SS 272), also a MIGRAINE III conversion, has a different radar fit in this view. She too has the BPS-2 on her tower and a different height-finder aft. The camouflage is the postwar Measure SS 17 G. Redfin's bridge has been widened. (USN)



▲ One of the most dramatic postwar conversions was the SSR radar picket submarine. Standard wartime *Gatos* now sprouted two or three large radar antennas, mounted on the sail or on prominent masts on the afterdeck. *Ray* (SSR 271) is seen in MIGRAINE III configuration on 26 September 1952. The antennas are (from the stern forward) a TACAN beacon, a BPS-3 height-finder on its bulbous base, and a huge BPS-2 air-search antenna on the sail. She has not yet had her bridge widened, a later modification for SSRs. (USN)

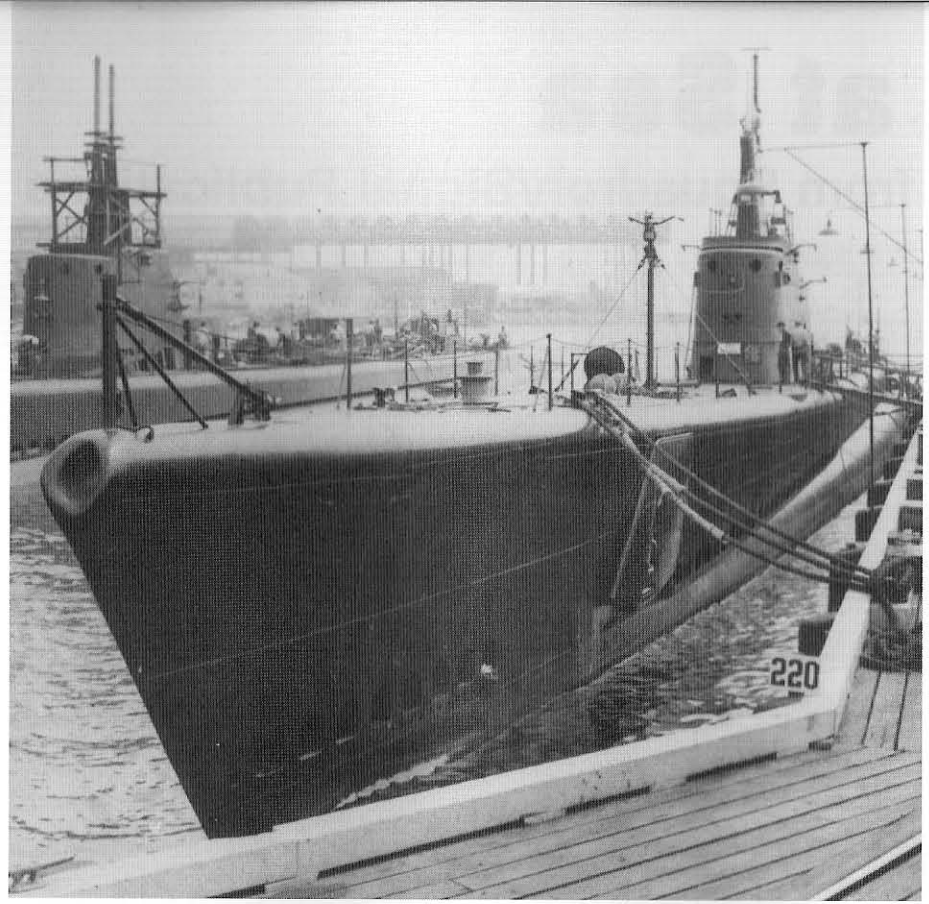


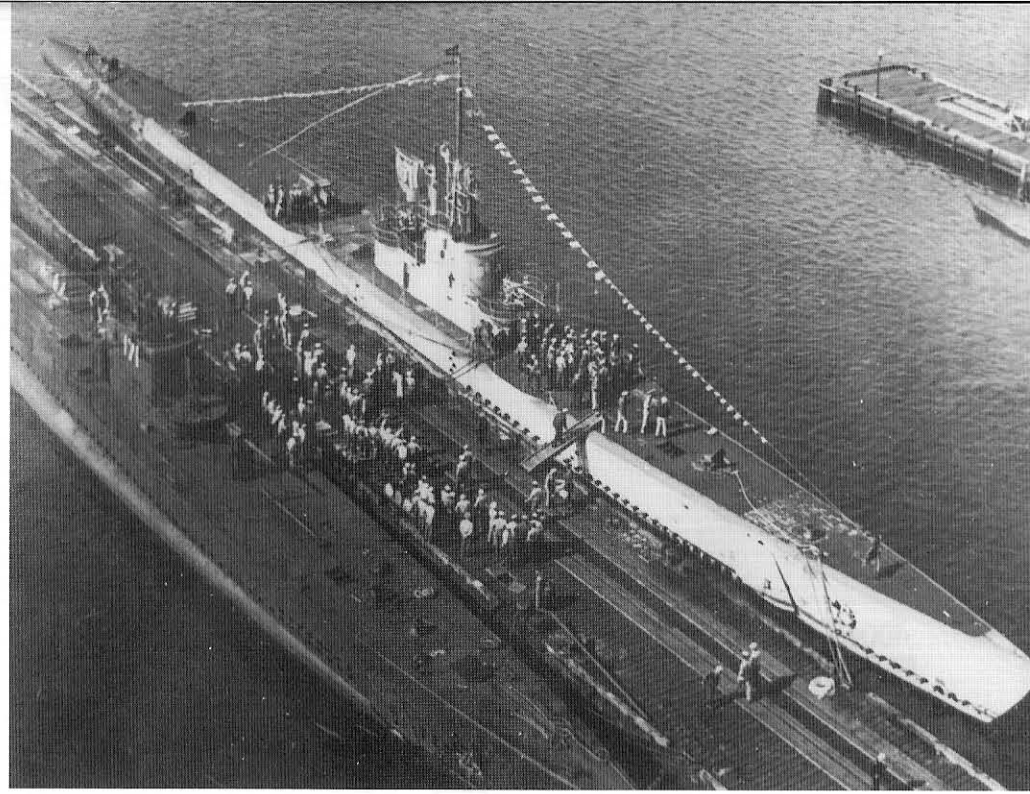


▲ SSK conversions came in a variety of shapes as the Navy experimented with how best to build a submarine capable of hunting and destroying other submarines. After an illustrious wartime career, *Cavalla* (SSK 244), seen here underway near Norfolk, Virginia, in June 1957, was modified to SSK standard in 1953 and served in the hunter-killer role until 1959. When it was realized that all submarines would need to fulfill that role, her designation reverted to 'SS.' She served until 1969 and is now a memorial in Galveston, Texas. (USN)

◀ *Angler* (SSK 240) is seen during conversion to SSK status at the Philadelphia Navy Yard in 1952. The most obvious change from her standard *Gato* configuration is the bulbous bow, which housed a BQR-4 array, an Americanized and enlarged version of the Balkon Gerät found on the captured German Type XXI U-boats. (Navsource)

▼ At least three boats, including *Sealion* (APSS 315), seen here in 1956, were modified to carry troops for clandestine landing operations. First designated 'SSP', she had a large watertight cylinder on the broadened deck aft of the tower large enough to hold an LVT. This was removed in 1955, but she still had the room to fit up to 123 troops. Her designation was changed to 'ASSP' in 1950, 'APSS' in 1956 and 'LPSS' in 1969, but her role remained the same until she was decommissioned in 1970. She was sunk as a target in 1978. (USN)





The incredibly long and interesting career of one *Gato* is illustrated on this page. *Barb* (SS 220) was the ninth *Gato*-class boat in hull number sequence and the twentieth to be commissioned out of 226 completed *Gatos*. (Above) She is seen here completing at the Electric Boat Company yard on 7 July 1942. (SFL) (Above Right) *Barb* undertook five patrols in the Atlantic but achieved no success before being transferred to the Pacific. Her first Pacific patrol began on 30 September 1943. Her first 'kill' didn't come until March 1944, but after that they came in a rush, and by the time she had completed her twelfth patrol in August 1945, she had accumulated the third greatest total of enemy tonnage sunk. For that last patrol she was fitted with a 5-inch (127 mm) rocket launcher on her afterdeck, which she used to carry out several bombardments on Sakhalin Island. She is seen here in September 1945, alongside a pier at New London, flying her commissioning pennant and all her battle honors, as she prepares to enter reserve status. Her tower was never cut down. (NHC) (Center Right) *Barb* was decommissioned in 1947, then brought back to active status in 1951. She is seen here on 21 July 1951, looking not much different than she did at the end of the war. She is painted in the dark Measure SS 11 G (Outside Gray #11 on vertical surfaces with dull Black at the stern). (NHC) (Below Right) In 1954, *Barb* underwent conversion to GUPPY IB configuration, which was similar to the GUPPY IA, but without upgraded electronics. She is seen here in November 1954, during the brief time she was working up with an Italian crew. She was decommissioned from the U.S. Navy on 13 December 1954 and immediately recommissioned into the Italian navy as *Enrico Tazzoli*. She served the Marina Militare until 1972 when old age finally caught up with her. Having served nearly continually for thirty years, she was stricken on 15 October 1972 and broken up at Livorno in 1975. (NARA)

Victory at Sea

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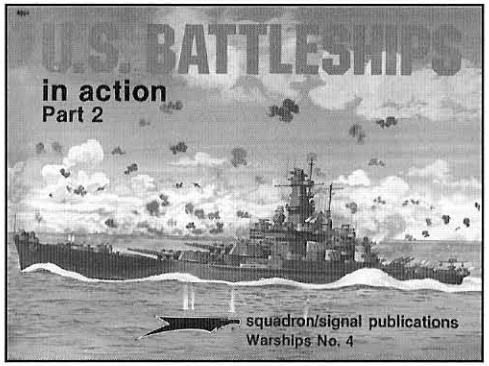

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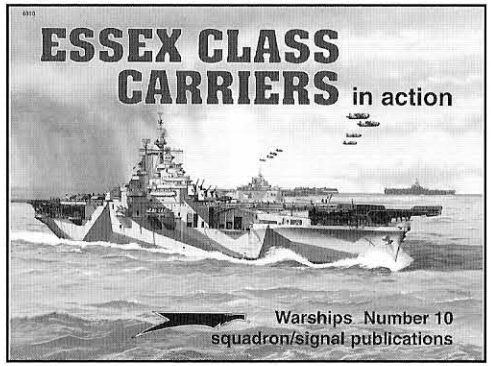

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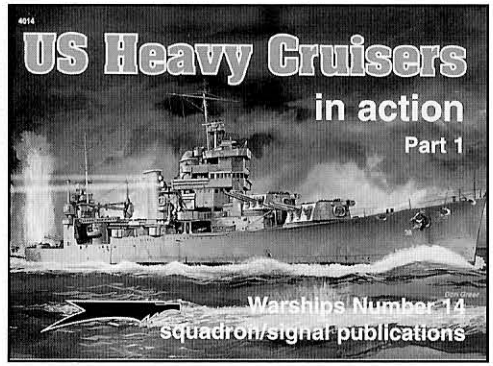

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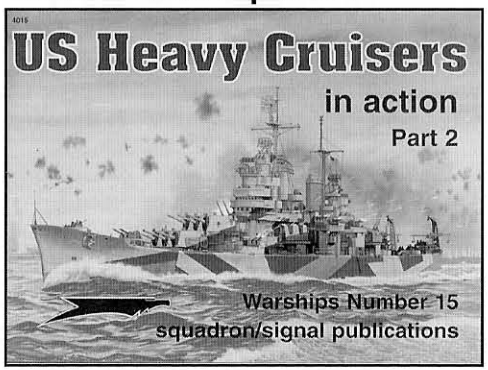

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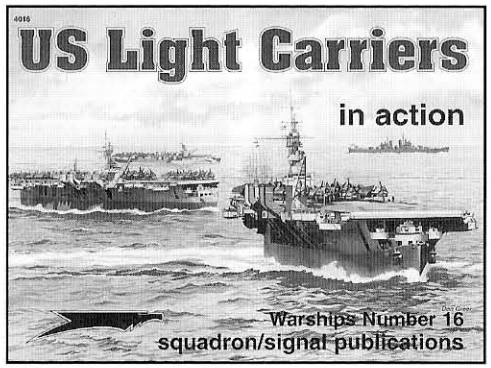
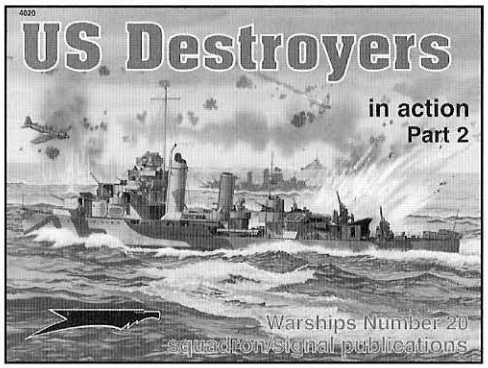


4016 US Light Carriers

4017 US Landing Craft



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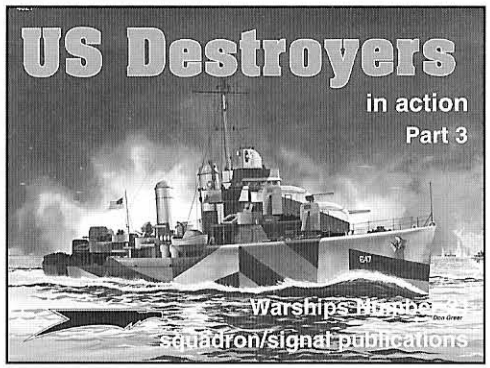

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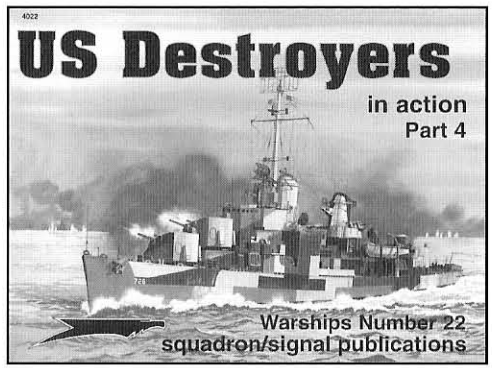

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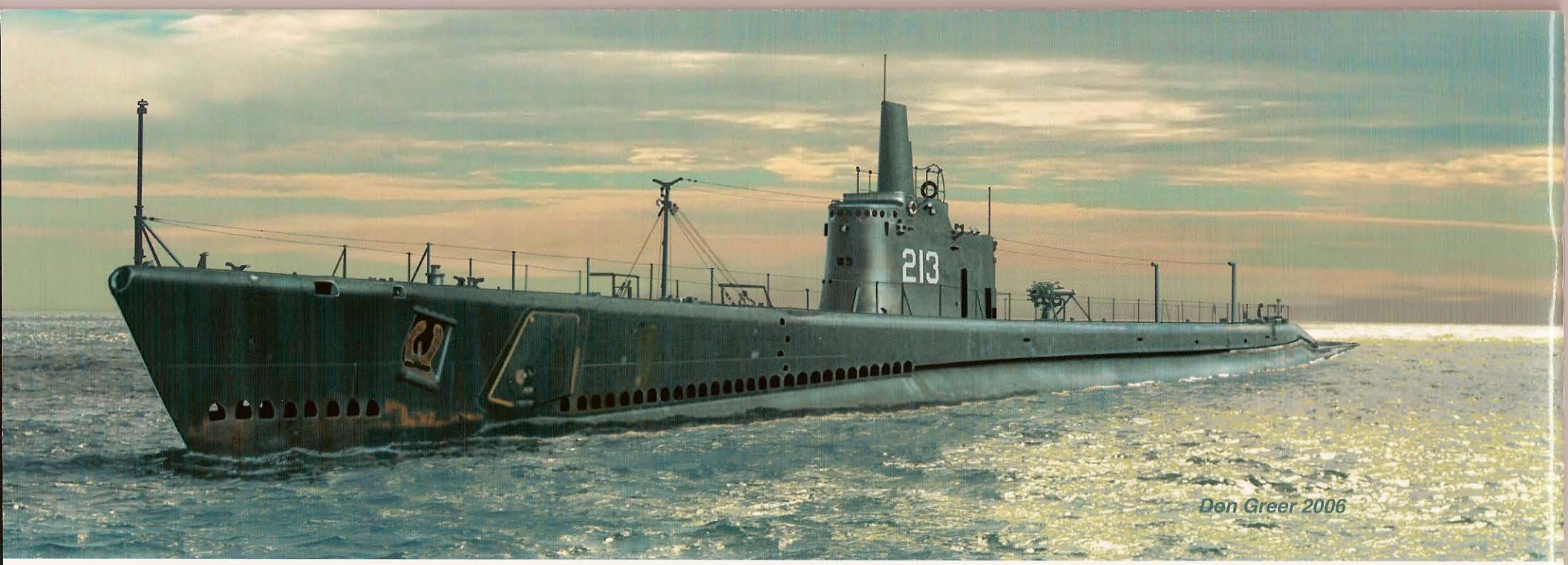

▲ USS *Greenling* (SS 213) as launched, 21 January 1942. *Greenling* received ten battle stars for World War II service and a Presidential Unit Citation for outstanding performance in her first three patrols. She remained in service until 1960, training reservists.

▼ USS *Volador* (SS 490) in Guppy III configuration with PUFFS, mid-to-late 1960s. She was laid down in June 1945, but her construction was halted in January 1946 and not resumed until August 1947. She was eventually launched as a GUPPY IIA in 1948.

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